Docket No. 2006-0431

Hawaiian Electric Company, Inc.'s Report on the October 15-16, 2006 Outage

Power Engineers Report

December 28, 2006

Hawaiian Electric Company

Investigation of 2006 Oahu Island-Wide Power Outage
PUC Docket Number 2006-0431

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Executive Summary

The State of Hawaii experienced a 6.7 magnitude earthquake west of the island of Hawaii at about 0707 hours on Sunday, October 15, 2006 (epicenter) and 0708:23 hours (Oahu). This was the strongest earthquake recorded in Hawaii in 23 years. According to the Hawaii Volcano Observatory, a second earthquake (6.0 magnitude) occurred approximately seven minutes later. Associated power system events led to island-wide blackouts for Hawaiian Electric Company, Inc. (HECO) on Oahu and Maui Electric Company, Ltd. (MECO) on Maui, although there was little apparent seismic damage to the electric systems on either island. Hawaii Electric Light Company, Inc. (HELCO) on the island of Hawaii maintained partial service with an isolated section, or "island" of generation and customer load in the Hilo area.

On Oahu, HECO restored power to all circuits by about 0155 hours on October 16, with pocket outages restored as they were identified through the morning and into the early evening of October 16. MECO had restored service to the majority of its customers by 1315 hours and the remaining customers by 1407 hours on October 15. HELCO had restored service to the majority of its customers by 1200 hours with the remaining customers restored by 2300 hours on October 15.

POWER Engineers, Inc. (POWER) was retained to investigate the causes of the outage on Oahu and provide professional opinions on the reasonableness of the responses of the HECO staff during the event and during power restoration. POWER's principal investigators, experts in power delivery systems and generation plant design and operation, traveled to Oahu on November 6 to November 10, 2006 and again on December 4, 2006 to discuss the events with the HECO staff, conduct field visits and gather information relevant to the events of the power outage and restoration on Oahu. Additional information was gathered via discussions over phone, through extensive follow up information requests, and analysis of system drawings and control schematics, relevant Company logs, studies and records, personnel interviews, and other applicable system documentation.

In summary, we find:

- The HECO system was in proper operating condition and appropriately staffed by personnel at the time that the earthquake struck. The unusually strong earthquake was the direct and proximate cause of the island-wide outage, setting in motion a series of events (through the operation of automatic relays and through operators' actions to protect the equipment) which resulted in loss of generation that eventually led to the system shutdown.
- In POWER's opinion, the HECO personnel reacted to the circumstances in a reasonable, responsible and professional manner. They applied training and experience in reacting properly to the changing system conditions based on the existing system configuration and established HECO operating practices to attempt to prevent the island-wide outage and to restore power as quickly as practical.
- In particular, after the complete shutdown of the system, a critical and prudent decision was made to simultaneously black start units at Kahe and Waiau power plants in parallel, which allowed the restoration to proceed as expeditiously as possible without the setbacks that would have resulted from delays that were in fact encountered at Kahe plant.
- In the restoration, HECO operated reasonably and in the public interest by following a systematic, orderly and methodical approach to add customer load to the system, allowing adequate time to inspect the system for earthquake damage, stabilize the operation of the generating units, and stabilize frequency and voltage on the grid.
- With the understanding that no system event will ever be identical to the one before it, we do make some specific recommendations which can be found at the end of this Executive Summary and in Section 5 of the report.

Discussion of Findings

The Hawaii Public Utilities Commission issued PUC Order No. 22986, Docket No. 2006-0431 ("PUC Order") requiring an examination of whether HECO, HELCO and MECO acted reasonably and in the public interest prior to and during the power outages. The PUC Order, Section II.C Preliminary Issues, page 8 and page 9, established the scope for this investigation.[1] This report addresses the following issues with respect to HECO.

1. *Aside from the earthquake, are there any underlying causes that contributed or may have contributed to the power outages?*

   We believe that the main underlying cause of the outage was the seismic action of the earthquake triggering mercury switches on generating units Kahe 5 and Kahe 6. These switches were used in the original equipment manufacturer's design to sense "Low-Low Fluid Level" on the Electro-Hydraulic (E.H.) governor system that regulates steam flow to the turbines. These switches on Kahe 5 and Kahe 6 operated the "Low Fluid Level Lockout" relays that prevent the E.H. system pumps from restarting to maintain the required operating hydraulic pressure, thereby leading to the loss of power from Kahe 5 and Kahe 6. The HECO system would have survived the trips of Kahe 3 and Honolulu 8: however the shutdown of both Kahe 5 and Kahe 6 exceeded the spinning reserve of the remaining units.

   The same style of mercury switches are installed in other fluid level monitoring applications in the Kahe 3, Kahe 4, Kahe 5 and Kahe 6 generating units, specifically on the feedwater level alarms and many of these alarms falsely activated during the earthquake.

[1] We understand that the preliminary issues were adopted as the issues for Docket No. 2006-0431 by Order No. 23155 (filed December 21, 2006).

2. *Were the activities and performance of the HECO Companies prior to and during the power outages reasonable and in the public interest? Specifically, were the power restoration processes and communication regarding the outages reasonable and timely under the circumstances?*

HECO's performance prior to and during the outage demonstrated reasonable actions in the public interest. The investigation found that prior to the outage, the system had all transmission lines in service and the appropriate generation available to supply load and reserves according to the approved HECO operating procedures. HECO had been consistently updating load shed studies applicable to system performance under a low frequency event. They have performed regular training; such as emergency response Incident Command exercises; the "System Dynamics and Generator Unit Response During Normal Operations and System Disturbances" training for the dispatch operators, generating unit control operators, and other operations staff; and black start training at Kahe power plant.

The actions of the HECO staff were certainly reasonable and timely, in the best interests of the public, and amounted to a good level of performance under the circumstances. With the advantage of calm hindsight, we can see that in a few cases there are details in which slightly different courses of action could have been taken. But we are not aware of any case where actions could be described as imprudent or likely to cause injury, or damage. In our opinion, actions by HECO personnel were reasonable, responsible and conducted in a professional manner.

The system restoration plan developed after the outage by the operations staff was reasonable based on steam generation as the first units to start and HECO management's historical knowledge of critical restoration issues. The plan appears to have been well executed by the primary trouble men (PTM), construction and maintenance crews, and substation crews. The pace of the restoration was balanced against the risk of tripping the generators restored to service, which would have required the system to be re-sectionalized and then re-started. The HECO internal communication systems operated adequately and did not hamper restoration.

The power plant staff exercised reasonable judgment in the planning and execution of the black-start procedures and responses to equipment failures encountered during a stressful time. The black start process was slowed due to equipment failure, troubleshooting and trips of the black start generators. The decision to proceed with black start simultaneously at Kahe and Waiau minimized the time required to restore black start power to the system. With this experience, we feel that HECO could improve, through the incorporation of some contingency planning and scenarios based upon recent events, training on black start procedures.

The operator trips of Kahe 3 and Honolulu 8 were reasonable and in the public interest considering the alarms, observations and previous experience, and considering that they each only had one turbine on line to consider as the source of the vibration. The operators also expected, and rightly so, that generation loss due to operator trips of Kahe 3 and Honolulu 8 were well within the HECO spinning and quick load pickup reserve at the time they tripped their units. They acted in good faith to minimize damage to the turbines that could result in unit outages of several months. Other operators with two units running also initially believed they had turbine vibration, but in the evaluation to determine which of the two units was causing the shaking they found that neither unit had an activated vibration alarm.

As a result of the seismic activity, the switches on Kahe 5 and Kahe 6 operated the "Low Fluid Level Lockout" relays that prevent the E.H. system pumps from restarting to maintain the required operating hydraulic pressure, thereby leading to the loss of power from Kahe 5 and Kahe 6. The fact that the Kahe 5 and Kahe 6 operators did not immediately respond to the "Low Fluid Level Lockout" alarms is understandable given that they were responding to a multitude of other alarms and system conditions[2]. However, even had the Kahe 5-6 operators recognized the significance of the "Low Fluid Level Lockout" alarm and that the E.H. Lockout had tripped, it is very doubtful that, in the three to six minutes available before Kahe 5 and Kahe 6 lost power, they could have performed a proper inspection and determined that the "Low Fluid Level Lockout" trip was due to a false indication by a mercury switch caused by the seismic shaking.

Our opinion is that operators for units Kahe 1-2 and at Waiau Power Plant exercised reasonable judgment in their decisions to attempt to "island" Kahe 1 and Kahe 2 and to keep the Waiau units connected to the grid, given the system circumstances, configuration of the 46 kV loads at Kahe compared with that of Waiau and HECO's operating procedures and requests by the dispatchers.

During the time of the event, it appears that the Supervisory Load Dispatcher (SLD) and Load Dispatcher (LD) took appropriate actions, using previous training and experience, to quickly and correctly determine that after the loss of power from Kahe 3 and Honolulu 8 that such loss would affect the system spinning reserve and called for startup of the Waiau combustion turbines (CTs) and the substation distributed generators (DGs) to make up the lost reserve. When Kahe 5 and Kahe 6 lost power the SLD quickly realized that the system was in jeopardy and initiated manual load shedding to try to salvage a portion of the system

[2] The significance of a "Lockout" relay in the utility industry is that it enforces the standard requirement for operators to inspect the condition of the equipment and verify the underlying cause of the relay operation. Once the fault is located and repaired or the system is inspected and or tested and found to be in operating condition, the "lockout" relay is manually reset and the system restored to operational status.

to provide restart power. Their actions were within the HECO Operations Division Policy Manual (ODPM) guidelines and POWER's only concern with their actions is with respect to the extended low frequency operation of the turbine-generator units.

After a complete shutdown of the grid, a critical and prudent decision was made at about 0809 hours on October 15 to black start units at Kahe and Waiau Power Plants in parallel. This decision restored initial power to the system at 1154 hours from Waiau Power Plant. If black start efforts had been solely focused at Kahe Power Plant, initial power to the system would have occurred at approximately 1430 hours. During initial attempts to restore black start power to the plant auxiliaries at Kahe, there were some problems in configuration of the black start generators and plant auxiliary system. Part of this was due to inexperience of a couple of plant staff in disconnecting the diesels from the grid and properly configuring the selected steam unit auxiliaries. However, these initial events did not significantly impact the system start time as this was occurring in parallel with other activities. A trip of the Kahe black start generators when Kahe 3 had fires in, due to an overload from auxiliaries, resulted in a delay bringing Kahe plant on-line and thus, Waiau 6 was the first unit on the bus. It must be recognized that black start of the Kahe and Waiau power plants is an activity that has rarely been required, the last instance being 15 years ago. Familiarity with the procedures for such significantly complex process can only come through training, rather than developing proficiency by actual application, and the training is limited by how much can be simulated while the other units are operating.

Once the black start process had been successfully completed, HECO operated reasonably, timely and in the public's interest by following a systematic, orderly and methodical approach to add customer load to the system to allow adequate time to inspect the system for earthquake damage, stabilize the operation of the generating units, and stabilize frequency and voltage on the grid. If the dispatchers attempted to add larger blocks of load, especially this early in the load restoration process, the likely result would have been much larger frequency and voltage fluctuations than experienced during the restoration. The control operator would then have experienced more difficulties controlling the operating generating units and stabilizing system voltage and frequency. Pickup of larger load blocks could also have resulted in a trip of Waiau 6 and requiring that the black start sequence be started over from the beginning including re-sectionalizing of the electric grid. This would have resulted in a delay of several hours with significant adverse consequences for the HECO and customer equipment operating on emergency power, and for critical facilities.

We have briefly reviewed the reports of the experiences of the electrical systems on Maui and the island of Hawaii on October 15, 2006, to consider possible comparisons with Oahu, particularly in regard to the duration of interruptions of supplies to consumers. We note that the generation technologies employed, the much smaller electrical systems, and the smaller sizes of individual generating units on Maui and the island of Hawaii, are quite different from those on Oahu. For this reason, the response to an exceptional system event such as that experienced on October 15, and the times for re-starting large-scale generation, can also be expected to be quite different. Our present conclusion, in advance of any detailed reviews of the Maui and HELCO systems, or of their responses to the October 15 earthquake, is that it is difficult to make a direct comparison between the HECO, MECO and HELCO experiences, and it could be misleading to do so.

3. *Could the island-wide power outages on Oahu and Maui have been avoided? What are the necessary steps to minimize and improve the response to such occurrences in the future?*

In POWER's opinion, the HECO personnel reacted to the circumstances in a reasonable, responsible and professional manner. They applied training and experience consistent with HECO operating practices in a deliberate effort to prevent the island-wide outage on Oahu and to restore power as fast as practical. (POWER's opinion on the Maui outage will be provided upon completion of the separate study of the Maui outage due on March 30, 2007.)

Kalaeloa Combustion Turbine 2 remained on line, supplying local auxiliary or 'house' load for some time, until it had to be shut down for operational reasons. In the case where one or both of the Kalaeloa combustion turbines continue to operate following a system disturbance and isolate or 'island' to local load, they might be used to restart the grid, if the 138 kV substation equipment is reconfigured to allow them to close on the "dead" bus bar of the transmission system. This is one suggestion on how to minimize and improve response to another island-wide outage.

Recommendations

The detailed recommendations from Section 5 are summarized below.

1. Review the "E.H. Low Fluid Lockout" control logic schemes for the motors driving the E.H. pumps for the main steam valves for Kahe 5 and Kahe 6. Evaluate replacement of the 86 LFT lockout with a non-latching relay while maintaining plant safety and proper operation. The controls should retain the present automatic tripping of the motors on low-low fluid levels and prevent re-starting while those low-low levels continue to be detected. The low-low fluid level alarm should also be maintained as long as the low fluid level condition is detected. We would like to note that HECO is presently acting on this recommendation.
2. Investigate replacing the mercury-type level switches presently used in the E. H. system and in the horizontal feed water heaters for the Kahe units, with a type or types less likely to give false indications under earthquake conditions.

3. Assess the possible employment of the Kalaeloa combined cycle block, to allow the use of its combustion turbines to re-power "black" transmission circuits.
4. Undertake a study, in the light of the experience of October 15, 2006, and subsequently update, to the extent appropriate, its low frequency tripping scheme based on the results of the study.
5. Assess the minimum frequencies at which each of HECO's steam turbine generating units can safely operate at full load, including a determination of reasonable durations of full load operation at various frequencies below the 60 Hz nominal.
6. Visually inspect the last row of Low Pressure (LP) turbine blades on Waiau 5, Waiau 7, Waiau 8, Kahe 1, and Kahe 2 for cracking and/or lacing wire damage by viewing from the exhaust spaces, or when the units are offline. We understand that Kahe 1's LP turbine blades were inspected during a scheduled overhaul after the earthquake. Inspection of the Kahe 1 LP section has not revealed any visible damage to Kahe 1.
7. Assess the system restoration process following an island-wide blackout to determine the best order for generator startup that would allow load to be added in a safe and expeditious manner while carefully retaining frequency and voltage stability. This study should take into account 1) the sequencing of the restoration for facilities critical to stabilizing the HECO system, 2) address practical priority restoration of critical customers and support services on Oahu, 3) the effect of the HECO 138 kV transmission system capacitance under no-load or light-load on system voltages during restoration, 4) flexibility in the restoration process to account for differing contingencies, and 5) the use of the planned Campbell Industrial Park combustion turbine (which will have black start capability) and possible use of the Kalaeloa CTs.
8. Evaluate black start procedures and training to account for equipment failure contingencies and communications across simultaneous units black starting.

9. Assess the feasibility of providing additions to physical equipment and/or software for capture and storage of a reasonable dataset (e.g., a one hour snapshot period) for all Distributed Control Systems (DCS) information, for each generating unit equipped with a DCS.

1 Introduction

The State of Hawaii experienced a 6.7 magnitude earthquake west of the island of Hawaii at about 0707 hours on Sunday, October 15, 2006 (epicenter) and 0708:23 hours (Oahu). This was the strongest earthquake recorded in Hawaii in 23 years. According to the Hawaii Volcano Observatory, a second earthquake (6.0 magnitude) occurred approximately seven minutes later. Associated power system events led to island-wide blackouts for Hawaiian Electric Company, Inc. (HECO) on Oahu and Maui Electric Company, Ltd. (MECO) on Maui, although there was little apparent seismic damage to the electric systems on either island. Hawaii Electric Light Company, Inc. (HELCO) on the island of Hawaii maintained partial service with an isolated section, or "island" of generation and customer load in the Hilo area.

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Subsequent to POWER being retained by HECO for its own investigation, the Hawaii Public Utilities Commission issued PUC Order No. 22986, Docket No. 2006-0431 ("PUC Order") requiring an examination of whether Hawaiian Electric Company, Inc. (HECO), Hawaii Electric Light Company, Inc. (HELCO) and Maui Electric Company, Ltd. (MECO) (collectively "the HECO Companies") acted reasonably and in the public interest prior to and during the power outages. The PUC Order, Section II.C Preliminary Issues, page 8 and page 9, established the scope for this investigation.

The PUC Order identified the following investigation subjects:[3]

1. Aside from the earthquake, are there any underlying causes that contributed or may have contributed to the power outages?
2. Were the activities and performance of the HECO Companies prior to and during the power outages reasonable and in the public interest? Specifically, were the power restoration processes and communication regarding the outages reasonable and timely under the circumstances?
3. Could the island-wide power outages on Oahu and Maui have been avoided? What are the necessary steps to minimize and improve the response to such occurrences in the future?
4. What penalties, if any, should be imposed on the HECO companies?[4]

[3] We understand that these four issues were adopted in Order No. 23155 (filed December 21, 2006) in Docket No. 2006-0431.

In addition, a reference under II.A Discussions, at the bottom of page 7 states: "... there may be some benefits to being able to compare the different utility systems on each of the three affected islands. These differences can and should be explained in the context of the outages and the varying restoration times."

From the PUC Order, HECO established the main statement of work for POWER Engineers to investigate and provide expert opinions with respect to the island-wide blackout and restoration on Oahu with follow-up reports for HELCO and MECO. POWER's investigation focused on five primary topic areas for the HECO transmission system, dispatch center and power plants.

These five primary topic areas are:

- Configuration prior to the event, to include operating procedures and prior training relevant to the event.
- Transmission system, dispatch center and power plant operator actions and automatic protection system action during the interval between the time when the earthquake seismic waves reached Oahu and the onset of the island-wide blackout.
- Personnel actions and equipment operations during the interval between the blackout and the return of the first generating units back on the grid.
- Restoration of the power grid from the time the first unit came on line until restoration of service to all customers on October 16.
- Comparison of the root causes and restoration times of the HECO, HELCO and MECO outages. (A preliminary comparison will be made for the December 28, 2006 submittal, but this section will not be concluded until the investigations are complete for HELCO and MECO.)

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[4] This report does not address this subject.

2 Sequence of Events

2.1 Background

Transmission and Distribution System

The HECO transmission and distribution system consists of seventeen 138 kV transmission substations, one hundred thirty four distribution substations, thirty two 138 kV transmission lines, sixty seven 46 kV sub-transmission lines, and four hundred fifty five 12 kV distribution feeders circuits. The 138 kV and 46 kV circuits are interconnected with redundant circuits that provide multiple options for supplying power to the distribution substations to increase reliability. The transmission system has been the subject of many reviews, in part because of the transmission-related issues that were the primary causes of previous island-wide outages in 1983 and 1991. In those cases, one transmission line was out of service for maintenance when a second transmission-line faulted. Previous investigative reports resulted in numerous recommendations for transmission system additions and generation plant equipment modifications intended to prevent recurrence under similar circumstances.

Numerous system studies have been performed by HECO and its consultants analyzing transmission system improvements proposed by the 1983 and 1991 outage studies. Four of these studies investigated load shed schemes, relay set points, and load blocks to trip to match generation and load initiated by multiple transmission system contingency events. The latest settings for the Underfrequency Load Shedding Scheme and estimated load shed base on morning peak are:

- Kicker Block; 58.5 Hz, 10-second delay; approximately 38.6 MW, 12 – 12 kV breakers
- Block 1; 58.0 Hz, 0-second delay; approximately 87.5 MW, 32 – 12 kV breakers

- o Block 2; 57.7 Hz, 0-second delay; approximately 73.7 MW, 1 - 138 kV, 4 - 46 kV and 15 – 12 kV breakers
- o Block 3; 57.4 Hz, 0-second delay; approximately 89.3 MW, 1 - 138 kV, 7 - 46 kV and 2 – 12 kV breakers
- o Block 4; 57.2 Hz, 0-second delay; approximately 83.8 MW, 1 - 138 kV and 7 - 46 kV breakers
- o Block 5; 57.0 Hz, 0-second delay; approximately 40.8 MW 3 - 46 kV breakers

The Undervoltage Load Shedding Scheme consists of four blocks with 27 – 46 kV breakers that shed approximately 35% of the system load.

Operations

Power supply operations are described in the confidential internal HECO Production Department "Operating Division Policy Manual" (ODPM). Included in the ODPM are the generation spinning reserve and quick-load pickup that HECO should maintain during normal operations[5] and the operating procedures for events where system frequency decays below 59.5 Hz.

System operations and management are performed by personnel assigned to the Dispatch Center located at HECO's Ward Avenue facility. A new Dispatch Center was recently constructed and began full operation at the end of March 2006. HECO's Dispatch Center is state of the art and is

[5] Spinning reserve, excess spinning reserve, and quick load pickup are important terms with respect the ability of the HECO system to withstand the sudden loss of a generation unit.

- o Spinning Reserve – The sum of the capabilities of the operating units less the capability of the largest operating unit must be greater than or equal to the estimated peak load. This mean that the system will normally carry enough "spinning reserve" equivalent to the capacity of the largest operating unit so that, with loss of the largest operating unit, the system can still meet the anticipated peak load.
- o Quick-Load Pickup – Sufficient generating unit capability must be available such that, upon trip of any one unit, the remaining units will have sufficient quick load pickup capability to restore system frequency to at least 58.5 Hz within three seconds after trip.
- o Excess spinning reserve is the amount of "firm" generator capacity on line that exceeds the minimum requirement established above.

comparable to other mainland utilities' dispatch centers. The Dispatch Center has seven work stations and a large central wall display for the Energy Management System (EMS). This system has an Automatic Generation Control (AGC) function which continuously controls the dispatch of generators and displays this information on the wall screen and computer monitors. The AGC screen (See Figure 1) shows the system load in megawatts (MW), system aggregate generation output, spinning reserve requirement, excess spinning reserve, quick load pickup requirement and excess quick load pickup, and frequency along with other quantities related to the economic dispatch of the generation. Generating units are brought on line and taken off line according to the Unit Commitment Order established by System Operation and according to changing load requirements.

The Kahe and Waiau power plants are each made up of three pairs of boiler/turbine/generator sets. Honolulu power plant has one pair of boiler/turbine/generator sets. Each pair of steam units has one control room that monitors and operates two units. Waiau 7-8 control room also remotely operates the Waiau 9-10 combustion turbines. Each pair of steam units shares a control room staffed by a Control Operator (CO), a Junior Control Operator (JCO) and an Equipment Operator (EO). Kahe power plant has one Utility Operator (UO) that supports non-unit-specific activities. Waiau power plant has two Utility Operators – a Regular UO (RUO) that supports steam unit activities including starting and shutting down cycling units, and an Outside UO (OUO) that supports fuel infrastructure and combustion turbine activities. Each power plant is staffed with a Shift Supervisor who is responsible for the day-to-day operations of the power plant. Each pair of steam units covers approximately 30,000 square feet and has 7 to 10 floor levels for the equipment.

Baseload units are economically dispatched to meet system requirements, including meeting spinning reserve and quick load pickup, and operate from full output to minimum output on a daily basis. The "baseload" terminology in this instance indicates that the machine is connected to the bus and producing power 52 weeks per year, 24 hours per day, unless it is out of service for maintenance. For HECO, Kahe Units 1 through 6, Waiau 7 and Waiau 8 are baseloaded units. Waiau Units 3 through 6 and Honolulu Units 8 and 9 cycle each day, with units being disconnected from the bus and "bottled up" at night to preserve steam pressure/temperature. Each morning, cycling units are restarted and synchronized to the system according to the commitment schedule. The Waiau combustion turbines, Units 9 and 10, and the distributed generators are usually used only during peak load periods, since they are the least economic units to operate. The Independent Power Producer (IPP) plants comprised of H-Power, AES and Kalaeloa are dispatched as baseload plants.

Black start procedures are identified in the Power Supply Operation and Maintenance Department, Operating Division Procedure, Black Plant Startup Operations for the Kahe generating plant Units 1 through 4. Waiau power plant uses Waiau Station "Simulated Black Plant" checklists for the various operating positions.

Generation plant units are referenced as follows throughout the report with respect to the control room staffing. Individual units will be designated by K1, K2, etc.

- Kahe 1 and Kahe 2 (K1-2)
- Kahe 3 and Kahe 4 (K3-4)
- Kahe 5 and Kahe 6 (K5-6)
- Honolulu 8 and Honolulu 9 (H8-9)
- Waiau 3 and Waiau 4 (W3-4)
- Waiau 5 and Waiau 6 (W5-6)
- Waiau 7 and Waiau 8 (W7-8)
- Waiau 9 and Waiau 10 (W9-10

Relevant Training

In addition to basic operator training, on-the-job training and other normal operations training, HECO performs Incident Command table-top exercises twice a year to practice HECO's emergency response planning, one component of which is coordination with federal, state and municipal agencies. The focus of Incident Command exercises has been on major disasters such as hurricanes and oil spills.

Black start hands-on training is performed on occasions in which Kahe Units 1, 2, 3 or 4 are returned to service after a maintenance outage. Most recently, HECO performed a hands-on black start training exercise on July 20, 2006 when Kahe 3 returned to service from a maintenance outage. The procedure was performed successfully and the unit returned to service in five hours under a training scenario. Such hands-on black start startups are conducted on a regular basis, approximately once per year.

Waiau normally runs a simulated black plant startup once a year. The last time this was performed was February 14, 2004 on W6. On August 21, 2005 the simulated black plant startup was aborted due to an intermittent fuel control valve leak. Waiau personnel did not attempt a simulated black plant startup in 2006 pending repairs to the fuel system.

Dynamic Stability Event Training – HECO has been presenting "System Dynamics and Generator Unit Response During Normal Operations and System Disturbances" training for the dispatch operators, generating unit control operators, and other operations staff. There have been seven training sessions to date for management, dispatch, engineering and plant operations personnel. The last session held before the October 15 outage was on October 13, 2006. This training describes system operation scenarios and issues that had direct application to this outage.

2.2 System Conditions at 7:00 AM Sunday October 15th

On Sunday October 15, prior to the earthquakes, the 138 kV transmission and 46 kV sub-transmission systems were in their normal configuration with all lines in service. No transmission maintenance outages were scheduled for the day. On the generation (supply) side, the generation commitments for a Sunday morning were normal. The power plant unit status from the System Load and Capacity spreadsheet from the EMS archive was as follows:

Table 1: Generation Status 0708:00 Hours October 15, 2006

Unit	Type	Status	Capacity (MW)	Output (MW)	Spinning Reserve	Excess Spin
Honolulu 8	Steam Turbine	Ramping Up	19.39	19.41	-0.02[6]	
Honolulu 9	Steam Turbine	Off Line for Maint.	0.00	0.00	0	
Waiau 3	Steam Turbine	Off Line; preparing for startup	0.00	0.00	0	
Waiau 4	Steam Turbine	Off Line; preparing for startup	0.00	0.00	0	
Waiau 5	Steam Turbine	On line; On EMS	57.00	25.43	31.57	
Waiau 6	Steam Turbine	Off Line; preparing for startup	0.00	0.00	0	
Waiau 7	Steam Turbine	On line; On EMS	87.00	50.88	36.12	
Waiau 8	Steam Turbine	On line; On EMS	87.00	62.95	24.05	
Waiau 9	Combustion Turbine	Off Line; Standby	0.00	0.00	0	
Waiau 10	Combustion Turbine	Off Line; Standby	0.00	0.00	0	
Kahe 1	Steam Turbine	On line; On EMS	86.00	46.29	39.71	
Kahe 2	Steam Turbine	On line; On EMS	86.00	36.80	49.2	
Kahe 3	Steam Turbine	On line; On EMS	89.00	48.39	40.61	
Kahe 4	Steam Turbine	Off Line: On overhaul	0.00	0.00	0	
Kahe 5	Steam Turbine	On line; On EMS	142.00	117.18	24.82	
Kahe 6	Steam Turbine	On line; On EMS	142.00	112.08	29.92	
HECO DG	Diesel	Off Line; Standby	0.00	0.00	0	
H-Power	Steam Turbine	On line; On EMS	46.00	45.86	0.14	
KLCT1	Combustion Turbine	Off line: Maintenance outage	0.00	-0.80	0.8	
KLCT2	Combustion Turbine	On line; On EMS	70.00	79.15	-9.15[7]	
KLST	Steam Turbine	On line; On EMS	20.00	13.11	6.89	
AES	Steam Turbine	On line; On EMS	180.00	179.92	0.08	
SYSTEM CAPACITY, LOAD AND RESERVE			1111.39	836.7	274.74	94.74

[6] H8 had just started and was on manual control resulting in the use of actual output of H8 for the Capacity value but with a time delay of 2 scans (4 seconds). The Output value is the actual output but with no time delay. Because H8 was increasing load at the time, Output value was greater than the Capacity value.
[7] For Kalaeloa, when only one CT is in operation (as was the case on October 15th), the correct Capacity values for Kalaeloa in single train configuration is 79 MW for KLCT1 capacity and 11 MW for KLST capacity.

The Dispatch Center was properly staffed with a Supervising Load Dispatcher (SLD), a Load Dispatcher (LD) and a Trouble Dispatcher (TD). The AGC archive indicated a spinning reserve of 274.74 MW with an excess of 94.74 MW based on 180 MW minimum spinning reserve. The Dispatch Center staff were conducting routine monitoring of the system conditions and supervising the startup schedule of generation as demand for power began to increase.

Kahe power plant staffing was normal, with the exception that Kahe 4 was on overhaul that morning. Because of this, the station superintendent responsible for all Kahe maintenance and operations was present, along with additional maintenance crews. Waiau and Honolulu plant staffing was normal for a Sunday. The personnel were conducting their normal routines of monitoring the plant conditions. Baseload units were increasing their output as the morning load demand increased and cycling units were either on line or in the process of starting up per the unit commitment schedule.

2.3 Earthquake and Island-Wide Outage Sequence of Events

2.3.1 Earthquake to Outage

We have developed the sequence of events from just before the earthquake to the outage using information from the EMS alarm log and HECO's employees present that day. This sequence of events coincides with the information displayed in the following figures. Figure 1 shows an example of the information displayed on the EMS AGC screens utilized by the dispatch personnel as the basis for their decisions. Figure 2 show the system generation/load and frequency with the timing of significant events on the HECO system from the time of the earthquake until K1 tripped. Figure 3 shows the megawatt output of the separate generating units and the system frequency. Some of the events did not generate an alarm so the timing is extrapolated from the EMS graphs, DCS records and relay event reports. The EMS, DCS and relays are not continuously synchronized to the same clock so time stamps do not correlate exactly between devices. Time stamps from information of the respective devices were used in this report. All times used in this report are based on the 2400 hour time clock, with the exception of the EMS time log which provides time stamps down to the second.

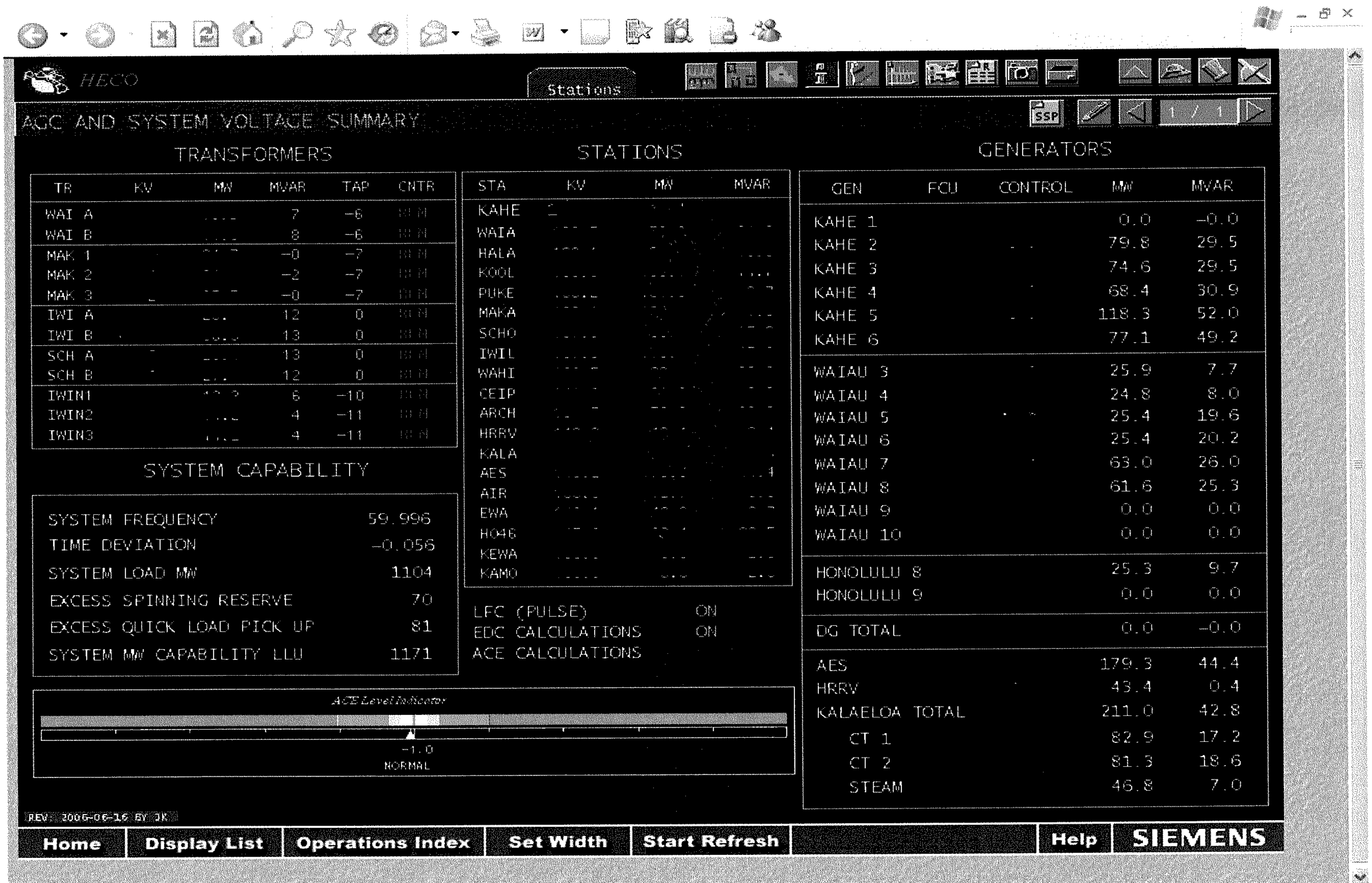

Figure 1: Example EMS AGC Screen (Station specific information was redacted for Homeland Security purposes)

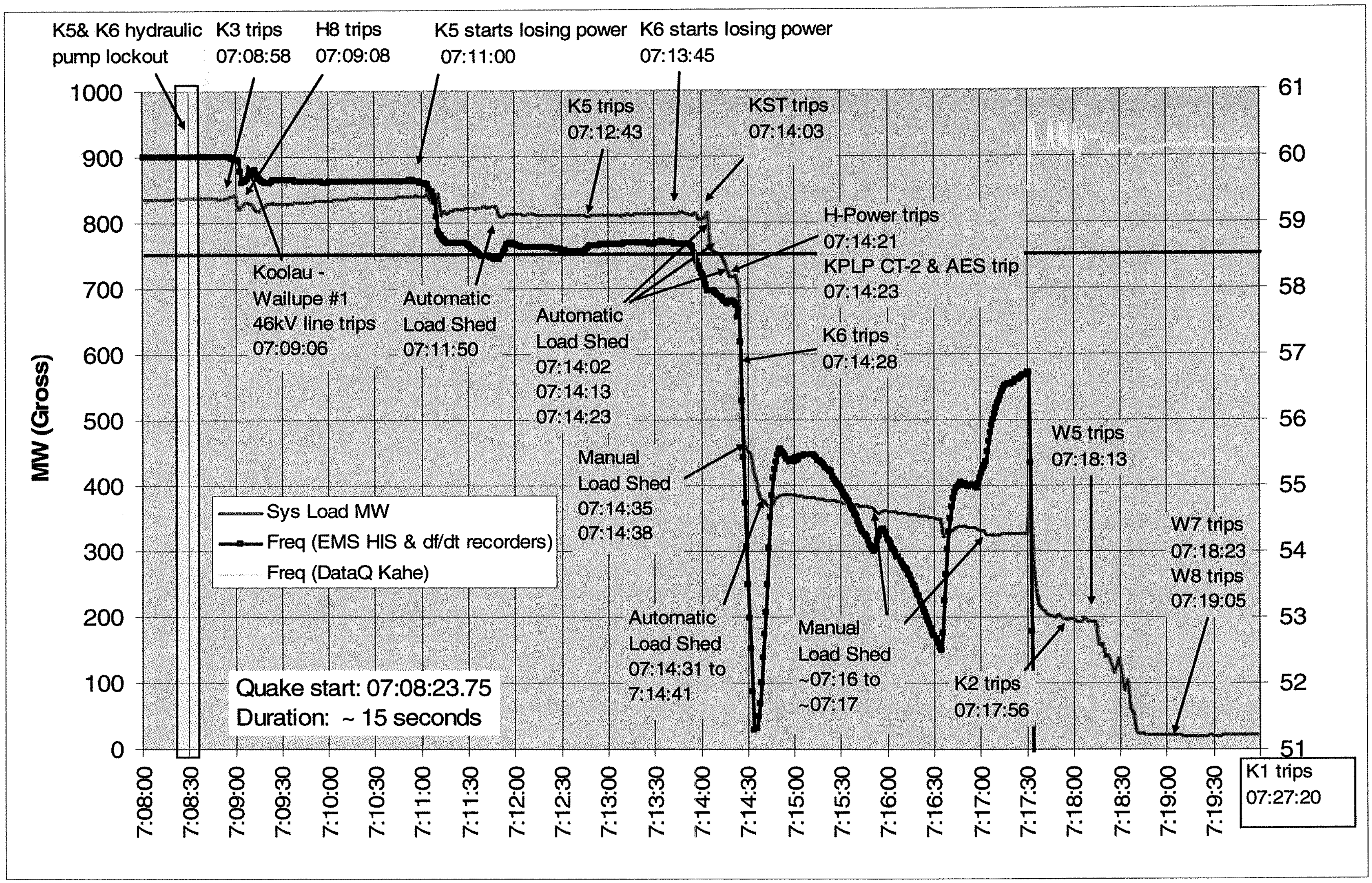

Figure 2: Generation versus Frequency Timeline October 15th, 2006

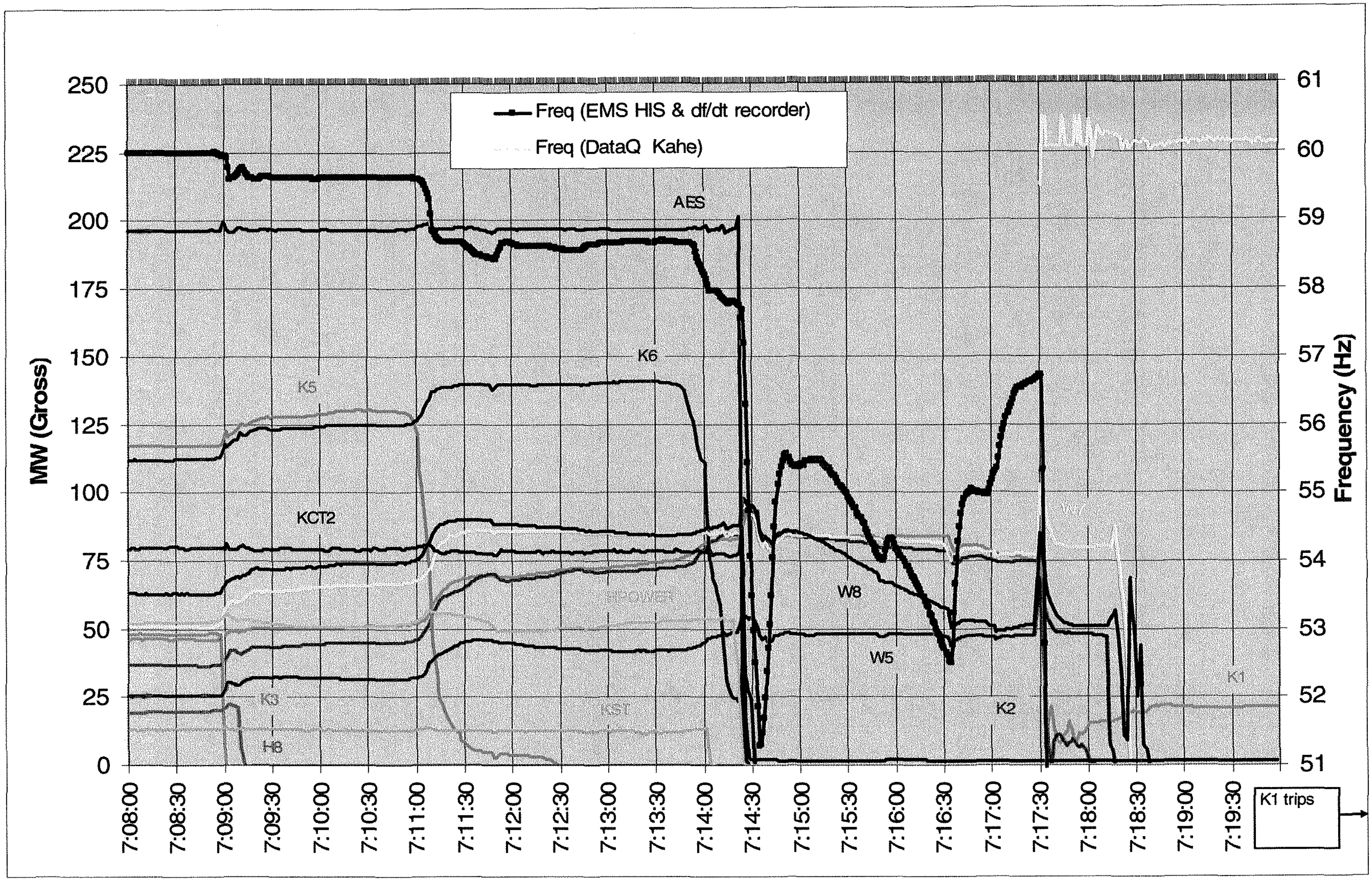

Figure 3: Individual Generator Output versus Frequency Timeline - October 15, 2006

Sequence of Events

7:00 – Normal transmission system configuration. 836.7 MW of load and losses. Frequency steady at 60 Hz. W5 and H8 just declared firm and on EMS. W6 was in the process of firing up.

7:08:23 – The first earthquake tremor reached Oahu and lasted 15 to 20 seconds. A second tremor followed about 7 minutes later with numerous aftershocks throughout the day.

7:08:30 – The shaking caused numerous alarms in K3-4 and K5-6 control rooms. A number of these were the boiler feedwater "Heater #1 High Level, Heater #2 High Level, Heater #4 High Level, and Heater #5 High Level" alarms. Two of the alarms at K5-6 were the Low Hydraulic Fluid Level Lockout alarm which indicated that the turbine governor Electro-Hydraulic (E.H.) system pumps had tripped and that the lockout device had activated (both K5 and K6).

7:08:58 – The K3-4 CO concluded, from the many feedwater Heater High Level alarms and the shaking of the control room, that feedwater must have backed up into the turbine (feedwater induction), causing vibration and shaking. The CO tripped K3 and called it in to the LD over the Hotline. Other generating units, including K5 and K6, began to pick up load. Frequency declined to about 59.7 Hz and then began to recover.

7:09:06 – The Koolau-Wailupe 46 kV #1 Line tripped (due to what was later found to be an insulator failure) and the load quickly auto-transferred to backup lines.

7:09:08 – The H8-9 CO tripped the H8 unit, believing that the turbine was causing the vibration and shaking that he experienced. He called it in to the LD.

7:09+ – The LD called for the startup of a combustion turbine (CT). The W7-8 CO heard over the Hotline that K3 and H8 had tripped, and on his own initiated the startup of the second CT as well.

7:11 – LD called for startup of the second Waiau CT; this was already in progress. The CTs were unable to complete the start sequence before the system collapsed (CTs take approximately 15 minutes from initiation of start to synchronization to the grid).

7:11:00 (approximate) – The K5 turbine hydraulic system pressure bled off and the turbine governor steam valves closed, causing K5's power output to drop off until the unit finally tripped on reverse power at 7:12:43. The remaining generating units attempted to pick up load but frequency declined to below 58.5 Hz.

7:11:50 – The EMS sent out an automated telephone page to executives and operations staff indicating that the automatic load shed scheme "kicker block" relays should have tripped the breakers to shed load. The frequency stabilized at about 58.7 Hz. The Schweitzer Engineering Laboratories (SEL) relays time-tagged the trip of three 12 kV breakers at 0712 hours and two at 07:14 hours (clocks on these relays are not continuously synchronized with the EMS clock). Seven of the SEL relays overwrote the event records so the trip times for those relays were not available. However, Figure 2 indicates that significant load was shed and the frequency stabilized above 58.5 Hz.

7:13:19 – The LD initiated remote startup of distributed generators (DGs), but the DGs were unable to complete the startup sequence and connect to the grid. (DGs take approximately 10 to 20 second from start to synchronization to the grid.)

7:13:45 (approximate) – The K6 turbine hydraulic system pressure bled off similar to K5, and the turbine governor steam valves closed. This caused K6's power output to drop off until the operator initiated trip of the unit at 7:14:28 to prevent tripping on reverse power. The frequency declined rapidly.

7:14:02 – Automatic load shed Block 1 operated at 58 Hz, 0-second time delay, but the frequency was still declining rapidly. Nine of the relays did not show a target or the event log had been overwritten so we cannot determine for a certainty that they operated. Five of the breakers were connected to send an alarm to the EMS, and the EMS alarm log indicated they tripped.

7:14:03 – The Kalaeloa steam generator tripped on underfrequency at 58.0 Hz with a 0.5-second delay while carrying 13.4 MW. (This relay was incorrectly set to trip at the alarm point and the setting has been corrected to 57 Hz with a 10 second delay.)

7:14:13 – Four breakers of automatic load shed Block 2 operated at 57.7 Hz, 0-second time delay as logged by the EMS. Three other breakers indicated that they tripped at 7:14:22 and 23. Four relays did not show a target but maintenance tests indicated that they operated as designed.

7:14:21 – H-Power tripped on underfrequency at 58.0 Hz with a 20-second delay.

7:14:23 –Kalaeloa CT-2 and AES both tripped on underfrequency. The frequency dropped to about 51.2 Hz. Numerous 12 kV and 46 kV breakers were automatically tripped system wide by automatic load shed scheme blocks 3, 4 and 5. Two relays from block 3 overwrote their event reports.

7:14:31 to 7:14:41 - The undervoltage load shed scheme tripped nine 46 kV breakers.

7:14:33 to 7:16:59 – The SLD manually shed load as fast as breakers could be commanded to open. The frequency recovered to about 55.5 Hz over a 15 second period.

7:16:31 - The undervoltage load shed scheme tripped two 46 kV breakers.

7:17:23 – The K1-2 CO conferred with the Kahe Station Superintendent, who was in the control room at that time, and said that he was going to island with house load and some feeder load. The Superintendent agreed and the CO tripped OCB 129 and noted 22 MW of load on the DCS screen.

7:17:28 – When the K1-2 CO tripped OCB 132, separating K1 and K2 and Nanakuli load from the rest of the island's system, the EMS indicated 9 MW on K2. The K1-2 bus frequency increased to 60.5 Hz. At about the same time, the frequency reading on the EMS (measured at Archer Substation) dropped to 0 Hz when the Archer substation breakers tripped on load shed.

7:17:56 – K2 tripped on low drum level due to the large decrease in output experienced by K2 when adjusting to the Nanakuli load. K1 was still holding on with Nanakuli load.

7:18:13 – W5 tripped.

7:18:23 – W7 tripped on loss of field.

7:19:05 – W8 tripped.

7:27:20 – The K1 Master Fuel Trip activated and shut off fuel to the boilers. As the pressure dropped below 1600 psia, the low drum level alarmed. After losing fires in the boiler and with a low drum level, the K1-2 CO tripped K1. The island-wide blackout resulted.

Summary of the System Dynamics

At the onset of what we now know was an earthquake, the system was operating normally with all transmission lines in service and generation properly dispatched to provide sufficient spinning reserve and quick load pickup in accordance with the published operating procedures. At the time of the earthquake, numerous feedwater Heater High Level alarms were triggered on K3, K4, K5 and K6. "E. H. Low-Low Fluid Level" sensors on K5 and K6 also alarmed and tripped both of the Low Fluid Level Lockouts (one 86 LFT for each unit) on the E.H. system that controls the valves regulating steam flow to the turbines for K5 and K6.

The operator trip of K3 dropped about 50 MW of generation and reduced system frequency by about 0.4 Hz. The remaining generation, including K5 and K6, despite the earlier trip of the E.H. pumps, began ramping up to pick up the load dropped by K3. Frequency began to rise back toward 60 Hz. The Koolau-Wailupe #1 46 kV line tripped and then transferred the load to backup circuits. The operator trip of H8 reduced the frequency to about 59.6 Hz, where it remained steady as the remaining generation, again including K5 and K6, ramped up to support the load.

Approximately two minutes after H8 tripped, the hydraulic system pressure on K5 bled down to the point where the turbine valves shut off steam flow to the turbine, resulting in a rapid decrease in output from about 130 MW to 20 MW. At this point, the frequency rapidly declined to about 58.8 Hz in about 15 seconds. The remaining generation, including K6, picked up the load. The decline of K5 power output from 20 MW to 0 MW slowed, along with the frequency decline, for about 1 minute until K5 tripped on reverse power. At less than 58.5 Hz and after a prescribed 10-second time delay, the automatic load shed "kicker block" operated. The load shed increased frequency to about 58.6 Hz where it remained for approximately 2.5 minutes. During this time the remaining generators were operating fairly steadily near maximum output and could not increase power enough to significantly raise the frequency in a short time.

At about 7:13:45, the turbine hydraulic system pressure on K6 bled off due to the E.H. Low Fluid Lockout preventing the motors from re-pressurizing the system, which allowed the turbine steam valves to close. The K6 turbine steam valves closed over a period of about 30 seconds, dropping the K6 power output until the operator tripped the unit to prevent a reverse power trip. The frequency declined over the course of the 30 second period to below 57.8 Hz along with the loss of power from K6. This portion of the frequency plot on Figure 2 indicates some curvature as tripping of automatic load shed blocks 1 and 2 struggled to offset the steady decline of the K6 power and the trip of the Kalaeloa steam turbine.

At the end of this 30 second frequency decline, H-Power tripped on underfrequency, exacerbating the load demand and generation imbalance and the system frequency again dropped abruptly. When the frequency dropped, Kalaeloa CT-2 and AES tripped on underfrequency as well as the remainder of load shed block 2 and load shed blocks 3, 4 and 5. The frequency dropped to about 51.2 Hz and then recovered over about 20 seconds to about 55.5 Hz as the combination of automatic undervoltage load shedding and manual load shedding by the SLD reduced the magnitude of the imbalance between load and remaining generation.

At this point, K1, K2, W5, W7 and W8 remained connected to the system. Frequency began to decline again as the W8 drum pressure declined and the boiler struggled to keep up with the added power demand over such a short time frame. The SLD continued to manually shed load and the system frequency recovered to about 56.7 Hz. At this time, after operating at a low frequency for several minutes, the K1-2 CO and Station Superintendent made the decision to separate the K1-2 units from the system to try to island to the local load with its auxiliaries due to the severe underfrequency situation, as indicated in the ODPM – Section IV, Part A, Severe System Frequency Depression.

As K1 and K2 were separated from the system and islanded, W5, W7 and W8 stayed connected to the remaining system load, in a separate electrical island from K1 and K2, and operated at low frequency, which caused them to trip about 45 seconds later. Twenty eight seconds after K1 and K2 islanded, K2 tripped on low drum level due to the load rejection upon separation. The last remaining unit, K1, remained connected to about 22 MW of load for eight minutes and 15 seconds with the local bus frequency settling to near 60 Hz. At this point, a Master Fuel Trip of the boiler caused by low fuel pressure required the operator to trip the K1 turbine. The island-wide blackout ensued as there was no remaining generation operating on the HECO system.

Load Dispatch Center Experience

Interviews with the Dispatch Center dispatchers indicated that when the initial shaking took place, the dispatchers were not sure what was happening. As the shaking continued, they determined that it was an earthquake. The building was shaking with sufficient violence that they had to hold onto furniture. Some took cover. After the shaking stopped they began to try to assess the multitude of alarms coming into the EMS.

The EMS equipment remained operating as normal. Just after K3 and H8 tripped, the LD announced over the Hotline that there had been an earthquake. The SLD and LD were quickly inundated by the number of alarms logging on the EMS (over 3,600 in the course of 20 minutes) and they began taking action based on the AGC generation summary information, voltage and frequency data.

The SLD on duty had attended the "Systems Dynamics and Generator Response During Normal Operations and System Disturbances" course on September 21, 2006. He stated that this training helped him immediately understand the implications when plant operators called in on the Hotline to report that their respective generators had tripped.

At this point the LD called for the start of one Waiau combustion turbine and then the second Waiau combustion turbine about two minutes later. Soon after, the LD initiated remote start of all distributed generation units. All remaining generators, including K5 and K6, responded with quick load pickup and the frequency stabilized, and it appeared that the system would be able to absorb the loss of K3 and H8. But then, K5 and K6 power rapidly declined. The CTs and DGs were not able to connect to the system during the frequency excursion and shut down. The automatic underfrequency load shed schemes began to operate, but the loss of four generating units in such short order reduced the frequency to below the 58.0 Hz underfrequency set-point for the H-Power low frequency relay. This underfrequency protective relay tripped the unit after the 20-second time delay. At this time, the frequency rapidly declined and the remaining underfrequency load shed blocks operated. At almost the same instant (7:14:23), the remaining IPPs (AES and Kalaeloa CT-2) were tripped by their respective underfrequency relays, further disturbing the balance of generation and load. The undervoltage load shed blocks then operated. The SLD began manual load shedding based on recent dynamics training to try to arrest the frequency decay and keep the remaining generating plants on line. Frequency was slowly recovering but remained significantly below 60Hz when K1 and K2 islanded to local loads. At this point, W5, W7 and W8 were the only units connected to the rest of the grid; they eventually tripped.

Power Plant Operator Experience

Interviews with the power plant staff indicated that most of them had not previously experienced an earthquake. All operators initially thought the shaking was due to turbine vibrations. Some later determined that the shaking was due to an earthquake. Others were not aware this had been an earthquake until it was announced on the Hotline. It is noted that the vibration alarms for the HECO steam units do not automatically trip the units. An operator assessment of the situation and decision is required whether or not to trip these units. Common to all of the units is that when load conditions suddenly change, they receive numerous alarms with respect to the changing conditions on the fuel supply, boiler operation, feedwater system, etc. that they must acknowledge and act on to maintain operation and safety of the plant. Numerous alarms were activating at the same time when the feedwater Heater High Level alarms and "Low Fluid Level Lockout" alarms registered in K5 and K6.

K1 and K2 Control Room

At the time of the earthquake, K1 and K2 began receiving multiple alarms, the operators initially believed they had turbine vibration and began to troubleshoot the alarmed equipment as fast as possible to determine which unit was vibrating. The vibration alarms had not activated, so the CO and JCO held off tripping the units to assess the other alarms. Both K1 and K2 picked up load as other units tripped off line. About 7:14:30, the K1-2 control room frequency meter pegged at 55 Hz, the lowest reading on the meter dial. About 3 minutes later, the CO discussed the situation with the Station Superintendent; they made the decision to island with local load. After islanding, K2 tripped on low drum level. K1 held on to about 22 MW of load until the "Master Fuel Trip" tripped on low fuel pressure and shut off fuel to the burners. The boiler lost pressure and the CO finally tripped the unit.

K3 and K4 Control Room

The K3-4 CO had only one turbine (K3) on line. K4 was on overhaul. The CO received many feedwater Heater High Level alarms during the shaking and he tripped the turbine believing he had a severe turbine water induction problem causing the vibration. This was the same problem that had caused major turbine damage to W8 the year before, and the K3-4 CO was specifically concerned about incurring similar damage[8]. The CO then reported the trip to the LD. The CO, JCO and EO then began to assess the alarms, secured the boiler and prepared for re-start.

K5 and K6 Control Room

The K5-6 operators also received multiple alarms, including many feedwater Heater High Level alarms, and believed they had turbine vibration. They quickly evaluated the Bently Nevada turbine vibration monitors. The vibration alarm had not activated on either unit, and the feedwater Heater High Level alarms returned to normal after the tremors subsided, so they held off tripping. In the case of K5-6, with multiple alarms, it was not readily apparent that the "Low Fluid Level Lockout" would quickly cause both units to lose hydraulic pressure and close the turbine steam valves and trip within minutes. In fact, both K5 and K6 responded with quick load pickup as expected when K3 and H8 were manually tripped.

The quick load pickup caused the K5-6 operators to focus their attention on stabilizing the boilers in response to the rapid increase in power output of both units. About 2.5 minutes after the earthquake, as the CO was about to lower load on K5, K5 power output began to drop rapidly on its own. At this point, the CO recognized that the E.H. pumps were tripped and attempted to restart the E.H. pump, but was not able to do so, due to the 86 LFT lockout. The CO reported that at the time he did not realize that a lockout relay had tripped, because lockout relays usually trip the unit. In this case, K5 and K6 had been responding as expected to the load increases. These

[8] K3 and K4 are similar to W7 and W8 in design and capacity ratings.

lockout relays are located on side panels out of direct view of the operators. The alarm panel light as installed by the OEM is labeled "Low Fluid Level Lockout" and does not readily identify that it is linked to the E.H. system. Since the governor hydraulic system was locked out, the turbine steam valves closed as the E.H. fluid pressure dissipated, shutting off steam supply to the turbine. K5 tripped on reverse power. At this point, the JCO and the UO were dispatched to secure the burners to avoid over-pressuring the boiler.

About three minutes later, while the activities progressed to secure K5 and stabilize K6, K6 began to lose power. The CO tried to start the K6 E.H. pumps but again the 86LFT prevented restart. K6 lost hydraulic pressure and the steam valves shut off power to the turbine. The CO tripped K6 to prevent a trip on reverse power. In the normal course of operation, the JCO or EO would travel to the E.H. unit(s), assess the fluid level, check the system integrity and radio back their findings to the CO. In this case, with the numerous alarms and other activities to stabilize the boilers for load pickup, they were not able to inspect the E.H. system condition before the turbines lost power.

W5 and W6 Control Room

The W5-6 CO received a phone call from his wife. She reported that she felt shaking and believed this phenomenon was an earthquake. While he was on the phone, the CO felt the shaking and hung up to check the turbine. His initial reaction was that they had a turbine problem. The regular utility operator (RUO) was in the control room at the time and went out to verify they did not have turbine vibration. There were no turbine vibration alarms activated. The operators then set to work trying to keep the boiler stable as their units' output picked up in response to other units tripping. When the frequency dropped below 57 Hz, the CO asked the LD if they should trip, but the LD asked them to hold on as they were shedding load to raise frequency. W5 finally tripped off line, but the CO indicated that they did not receive a specific alarm, protective relay target indications, or lockouts to indicate what actually tripped the unit.

W7 and W8 Control Room

The W7-8 control operators experience was very similar to that at W5-6. They did not get alarms during the earthquake but they were having difficulty sustaining boiler pressure after undergoing a rapid increase in loading while operating at less than 60Hz. Operators contemplated islanding their units to their respective auxiliary loads but were asked by the LDs to hang on during the severe low frequency operation. W7 tripped on loss of generator field. W8 also tripped but as in the case of W5, no alarms, protective relay targets, or lockouts indicated what actually tripped the unit.

IPPs

The IPP plants' low frequency protective relays operated and tripped H-Power, AES and Kalaeloa off line. Kalaeloa CT2 tripped to its house load but wasn't able to connect to a dead bus before shutting down.

Transmission System

The transmission system remained intact and continued to operate. The only line that tripped was the Koolau-Wailupe #1 46 kV line which had a fault due to an insulator failure. Load served by this line was automatically transferred to backup circuits. All indications from the EMS alarm log indicated that the automatic Under Frequency Load Shed (UFLS) and Under Voltage Load Shed (UVLS) schemes activated and assisted in shedding load as designed. There were two breakers that apparently did not operate, and 23 relays either did not provide a relay target or overwrote the relay event reports, so there is no conclusive indication whether the breakers operated. The SLD also manually shed load but due to the rapid decline in system frequency, was not able to sufficiently reduce the load to balance with the generation to restore frequency to above 57 Hz before the K1-2 CO tripped the units to island with local load.

2.3.2 Outage to System Restoration

Figures 4 and 5 show the general time line from the island-wide blackout up until all circuits and the vast majority of the customers were restored, at about 0155 hours on October 16, 2006. This outage differed from previous island-wide outages in two major respects. First, the transmission system remained intact and the outage was completely the result of generation plants going off line because of operator and automatic actions associated with the earthquake shaking. Second, because Oahu had experienced two earthquakes, the PTMs, Construction and Maintenance Crews (C&M), Substation and power plant personnel could not be certain that the equipment was undamaged. This second consideration led to a great deal of concern and caution when unexpected events occurred during the black start and restoration process.

In the event of an emergency, HECO follows its confidential Incident Response Manual (IRM), which provides guidelines for responding to events, including blackouts. The IRM includes procedures for assembling an incident command team, onsite response teams, communication protocols, and resources to respond. With respect to blackouts, because each outage is different and in each case different parts of the system grid/generators may or may not be available, each restoration plan will be unique. Each restoration plan, such as the one for October 15, takes into account the available system components, available HECO staff, and experience gained from previous restorations regarding prudent procedures to maintain system stability during the early stages.

The following information is based on interviews with management, the dispatchers, power plant operators, and from information gathered from the presentation that HECO Executives made to the Public Utilities Commission and the public, as well as information that was gathered from various sources including the new Energy Management System.

Numerous activities were taking place in the power plants as Power Supply personnel prepared to black start generating units at Kahe and a unit at Waiau. Simultaneously, the dispatchers, PTMs and management personnel were preparing the electrical grid for the first unit to come on line. In addition to preparing the system for restoration, key operations management personnel were developing a sequence for the restoration process (Incident Command). At that point in time, attention was not yet focused on the detailed customer restoration, but rather on a sequence that had to be followed to re-energize the HECO transmission grid.

The Incident Command Team met and established the primary objectives of the overall restoration plan which were:

1) restore power in a safe manner,

2) avoid damage to customer and utility equipment,

3) restore the transmission grid to provide power to the generating plants (from either Kahe or Waiau depending on what unit was on line first) so that startup power was available to start additional generating units,

4) ensure that there weren't islanded systems if Power Supply was able to simultaneously start generating units at Kahe and Waiau,

5) provide power to the independent power producers so that they could get their generating units on line as quickly as possible, and

6) re-energize the entire 138 kV transmission grid so that loads around the island could be restored.

During the time frame from about 0730 hours to 1154 hours, to when the first unit was brought on line, different working groups had to coordinate their efforts by communicating what was happening on the system as they prepared the electrical system restoration. The focal point of the communication was the dispatchers in the Dispatch Center who were ultimately responsible for coordinating the activities necessary to a successful system restart.

Load Dispatch Center and Load Restoration

Once Oahu lost electricity, the SLD dispatched the Primary Trouble Men (PTMs) on duty to begin preparing the system for restoration. Also, four additional PTMs were contacted to report to work. The PTMs prepared the stations by opening any 46 kV, 12 kV and 4 kV breakers still closed. They blocked the automatic transfer schemes which detect a dead bus and automatically switch the circuit to the live bus under normal system operation. These actions were done so that the SLD and LD would have control over the amount of load that would be added to the system when each breaker was closed reconnecting load. In addition, they visually inspected the stations and lines for any apparent seismic damage. They would then radio the Dispatch Center for the next assignment. Numerous additional staff reported in before being called to assist with the restoration. As additional staff arrived, they were assigned areas of responsibility for the restoration. The Operating Engineer reviewed the alarms log and found that only one 46 kV sub-transmission line had tripped, which was confirmed by the Test Engineer. Crews were also mobilized to drive along the lines where possible and to fly over the 138 kV lines to check for damage. Through these actions, the transmission and distribution system was prepared for restoration prior to the return of generation.

The Incident Command team began contacting the appropriate government agencies and emergency responders. Contact was made with the various federal, state and municipal agencies to keep all advised of the situation with the HECO electric grid status. A few of the senior personnel leading the Incident Command Team on the morning of October 15 had been on duty during the 1991 blackout, and their experience factored into the restoration activities. Their primary concern was the ability to manage the incremental load demand initially carried by a single steam unit operating at limited capability (approximately 70% drum pressure, single burner operation) and the potential for that unit to trip off line. Moreover, they were also concerned that unstable unit operations could result in exceeding environmental operating limits, thus requiring a forced manual shutdown of the unit. Either of these scenarios could have resulted in a return to island-wide blackout conditions and the necessity to black start the grid again. The SLD and additional senior staff that responded to assist with the restoration assessed the outage situation and developed a restoration plan.

At approximately 0809 hours the decision was made by the Manager of Power Supply Operations and Maintenance and the Manager of System Operation to black start both Kahe and Waiau power plants. At that time, the preliminary projected sequence of the generation black start based on the progress at the plants was that K3 would be the first unit on line at approximately 1030 hours followed by W6 at approximately an hour later. As a result, planning for the field activities to support initial load restoration was focused around Kahe. Due to delays with the black start operation at Kahe, System Operation was informed at 1034 hours that Waiau 6 would be the first plant on line so planning for initial load restoration efforts were refocused for restoration from Waiau. As it turns out, due to the complexity of the process and unforeseen problems encountered at both Kahe and Waiau Power Plants, W6 was the first unit on the HECO grid at 1154 hours. The black start difficulties encountered are explained in the Power Plants section below. HECO can black start both Kahe and Waiau stations and sync one station to the other as long as the station syncing in has only one unit operating and does not have significant local load connected.

Once W6 was on line, the first two 12 kV circuits to pick up local loads near the Waiau Power Plant were energized using SCADA control from the EMS. In addition, the 46 kV circuit for the Waiau Station Startup Transformer was also energized to provide auxiliary power for the other Waiau Units. With the auxiliary power from the HECO grid, other Waiau units could begin their unit startup process. After the first two 12 kV breaker closures to restore load, the W5-6 CO continued the process of attending to W6 to maintain boiler pressure as the unit picked up more load, while the LDs prepared for the next sequence of steps for the restoration of the 138 kV, 46 kV and 12 kV systems. This was a carefully managed process, especially between 1154 hours and 1357 hours when only W6 was on line, to prevent a trip of W6, which would require a restart, and to maintain operation within permitted environmental limits (to prevent an operator trip). W3 and W10 came on line at 1357 hours and 1407 hours respectively. At this time, load began to be added at a much faster rate with 24 breakers being closed between 1400 hours and 1500 hours.

Loads in the immediate vicinity of the Waiau Power Plant were restored methodically so that the control operator for W6 could stabilize various parameters of the unit including generator voltage and frequency as well as boiler pressure and temperature. Stabilizing and increasing the output of W6 under a black start condition is a slower process than the normal startup using the energized HECO 138 kV transmission grid. At the beginning of the restoration there was approximately an hour between energizing the first two 12 kV circuits and energizing additional circuits. During this hour, the W5-6 CO was busy controlling the system frequency and voltages to prevent damage to the system or to customers' electrical equipment and providing startup power to other Waiau units. Another significant concern during the time was that system frequency would swing to a level such that W6 and/or its auxiliaries could trip due to frequency swings resulting in a total restart of the black start process (see Figure 4). The CO was also controlling critical combustion parameters such as boiler pressure, water chemistry, steam temperatures, drum level, firing rate, environmental emission compliance, and others. These actions did not consume the entire hour but there also was an on-going process of adding burners to increase boiler pressure (thus increasing the MW capability of W6) and stabilizing combustion conditions as additional 12 kV circuits were energized, picking up more load. Typically, the boiler was able to stabilize combustion conditions within 10-15 minutes after additional load increases. With only one generating unit on line, the AGC program was deactivated because the system frequency needed to be manually regulated while load increments were added to W6 and as the CO worked to increase the output of W6.

While the W5-6 CO was stabilizing W6, the LDs were directing the PTMs and HECO crews to reset the 46 kV and 12 kV breakers around Waiau Power Plant in order to pick up more customer load. During the restoration, because of the unexpected earthquake event, personnel in the field identified a number of issues that had to be addressed. For example, as earlier described, underfrequency and undervoltage load shedding schemes had operated to separate load from the system in an attempt to arrest the system frequency decline or to alleviate low voltages on the system, respectively. As the LDs worked with the PTMs to restore the initial 46 kV and 12 kV circuits between 1300 hours and 1400 hours, the LDs were informed by the PTMs that they were unable to close some of the 46 kV and 12 kV circuit breakers. With the assistance of the dispatchers and the Test Engineer, the PTMs were directed on how to troubleshoot the problem with the breakers. In some cases, the underfrequency relays remained tripped and it was necessary to reset the relay before the breakers could be closed. This troubleshooting process slowed the restoration during the early afternoon between the hours of 1200 hours and 1300 hours. Other than the initial time spent completing these relay resets, it does not appear that these unanticipated field situations had a significant impact on the overall restoration time as additional LDs were working with other PTMs and HECO crews. However, this example demonstrates how a LD can become suddenly occupied with an issue on the system involving a PTM who needs an immediate response, and their ability to diagnose and resolve the situation directly impacts the speed at which they are able to restore power. Due to the number of PTMs and HECO crews working during this event, this was not an issue that significantly affected the overall restoration time.

Based on a review of event historical frequency and voltage data, there were severe system instabilities during the first few hours of the system restoration. Figure 4 shows the frequency swings and Figure 5 shows the voltage swings that occurred with line and load additions over the course of several hours during re-energization of the grid. The swings in voltage and frequency observed by the COs and the LDs obviously raised concerns. If the fluctuations in voltage and frequency had been allowed to worsen, they could have resulted in manual or automatic trips of the units that were on line, resulting in black start from square one. Understanding and anticipating the system volatility during start-up, HECO operated in an orderly and methodical manner to add load to the system so that there was adequate opportunity to stabilize the operation of the generating units, and stabilize frequency and voltage on the grid.

The next step was to energize the 138 kV transmission system between Waiau and Kahe to allow the Kahe units to synchronize to the Waiau units. The first circuit attempted was the Waiau-Kahe 138 kV line, which was the shortest and most direct path to connect Waiau units Kahe, but it failed to energize due to a breaker problem. The next attempt was to energize Kahe by way of Wahiawa which succeeded. Local Kahe load was picked up and a 138 kV ring was energized back to Waiau. Additional 138 kV circuits were energized to CEIP. Power was now available to startup and synchronize the available generating units at Kahe, Waiau, and the IPPs. In the process of adding load, the LDs focused on the areas surrounding the power plants to provide load to stabilize the power plants and the transmission voltages.

With the majority of the generation essentially located in the western region of the island and the majority of the loads to the east, the restoration sequence is necessarily dictated by the geographical layout of the loads in respect to where the power comes from. The Honolulu Power Plant, while located nearest to the downtown load center, is the smallest of HECO's power plants, is not interconnected with the grid at the 138kV transmission level, and lacks black start capability. Thus, the transmission grid had to be energized to provide startup power to the Honolulu Power Plant. As a consequence of the system's fundamental characteristics, loads around the Waiau plant were energized first in order to stabilize the first generating unit on line followed by loads in the vicinity of the Kahe plant to stabilize generation there once the first Kahe unit was brought online.

The data reviewed shows that while the 138 kV transmission grid was being energized, extremely high voltages were encountered. These high voltage conditions could have been the result of a) the capacitance created on the lines because of the lightly loaded system, b) the W6 CO trying to control the MW output of the unit and the voltage on the system, or c) a combination of both. In addition to concern over HECO's own equipment, the LDs had concern for the impact of this high voltage on customers' equipment. When a high voltage situation arose, quick action was taken on the part of the LD to bring the voltage within operating range. In some cases the transmission line was taken back out of service by using the EMS to remotely open the circuit breakers in order to prevent damage to the system. In other cases, the LDs worked with the PTM to add loads to the system such that the inductive loads offset line capacitance to lower voltages on the transmission system.

As more of the transmission grid was energized, LDs had greater flexibility on what loads they could restore. However, consistent with the overall objectives for the immediate operating period, LDs remained focused on energizing the transmission grid to get power to the power plants and the independent power producers to enable more generators to be started, thereby increasing the power available to restore customers.

In addition to the seismic forces, there was the concern of how the loss of power impacted HECO's own infrastructure. When there is no power on the electrical grid, HECO's transmission substations are backed up by station batteries that provide control power to devices in the field so that if necessary, LDs can operate them remotely from the Dispatch Center. As the outage continued and as LDs controlled devices in the field using backup DC power, they became increasingly concerned about draining the substation batteries to the point where there might be no power left to control the equipment remotely.

In addition, HECO's fuel supply is transported from holding tanks to the power plants primarily via pipelines. Thus, it was important to restore grid power to key fuel-related infrastructure and sites to ensure operating integrity and ability to provide for an adequate fuel supply to HECO's generators. Other fuel systems – for example, the diesel fuel supply for the generating unit startup – were also on the list of critical infrastructure components. HECO's Incident Command had to account for these types of consequences and concerns as they developed their plans to restore power to customers.

As the length of the outage increased "Cold Load Pickup"[9] began to be a factor that the LDs and power plant operators had to contend with when energizing circuits.

As power was supplied to the customers, situations arose when certain customers required HECO's assistance in order to reconnect to the HECO electrical system. This was the case with

[9] Cold Load Pickup is the term used to refer to the fact that the distribution feeders have lost load diversity (all refrigerators, electric water heaters, and air conditioners come on at once) such that the load, when first energized, is temporarily much higher than normal when the equipment is randomly cycling.

commercial and residential customers who owned on site generating equipment and were unsure of how to operate the equipment, or those who had problems while attempting to reconnect to the electrical grid. One example was a hospital that was being powered by its emergency generators. Though power had been restored to the distribution circuit that served the hospital, the hospital continued to operate on emergency generator power detached from the electrical system. The equipment that needed to be operated to reconnect it to the HECO power supply was owned and normally operated by hospital maintenance personnel. However, during the system restoration the hospital maintenance personnel had problems trying to reconnect their equipment to the HECO electrical system. Calls were made to a HECO contact person for assistance. As a result, a PTM was diverted from the broader system restoration activities to address the hospital's problem. The PTM worked with the hospital maintenance personnel to resolve the problem and the hospital was eventually restored to the HECO electrical system and no longer had to rely on their emergency generator for power.

For the remainder of the restoration period, HECO continued the methodical and cautious approach for the load restoration. As system load increased to several hundred megawatts and more generating units were brought on line, the system frequency and voltages became more stable and the pace of the restoration was accelerated. All through the process, however, the LDs coordinated the timing of the load restoration to provide the required time for the generating units, system frequency and voltages to stabilize.

The prioritization that the LDs were following was to restore power to the areas that had critical loads such as hospitals, sewage treatment facilities, the airport, police stations, fire stations, and military bases once the transmission circuits in the area of these critical customers could be energized. During the course of the restoration, HECO executives were in communication with key government agencies such as the Oahu and State Civil Defense and the Department of Transportation, whose input was considered in the restoration prioritization.

In some cases, the instinctive desire to restore power to critical customers first was tempered by the prudence and efficiency of restoring loads along the way, as a LD directed a PTM from one location to the next. If for example, a PTM or HECO crew had to pass near a substation before arriving at another that served a critical customer, it made sense to restore those nearby loads first before moving to the more remote substation and then backtracking.

In addition, after communication with the State Department of Education (DOE) when only a small portion of the load had been restored, HECO committed to have power to the schools by the next morning so that DOE was able to plan accordingly, knowing that hundreds of thousands of students would be able to attend school as planned and parents would not have to make alternate plans for their children.

Once all circuits were restored about 0155 hours on October 16, the Dispatch Center began to focus on resolving open trouble tickets. Many trouble tickets received earlier on October 15 were generally based on the island-wide outage. Most were resolved once the corresponding substation circuit breakers were closed and service was restored. By 0155 hours on October 15, many customers had gone to bed before power was restored and were not aware that they were in a pocket outage until they awoke the next morning, so a number of pocket outages were not recognized until these customers began calling these in early in the morning of October 16. Many pocket outages were caused by fuse, switch and secondary wire failures. As pocket outages were called in, trouble tickets were established and all PTMs, C&M crews and Substation crews available to work that day were dispatched to locate the problem and restore service.

Table 2: General Timeline for the Restoration of Geographic Areas.

Restoration Area	Approximate Circuit Restoration Time	Comments
Waiau Power Plant	1200	Stabilizing Load
Portions of Waiau, Waimalu, & Pearl City	1205	Stabilizing Load
Portions of Aiea, Kaonohi and remaining Waiau, Waimalu, Waimano & Pearl City	1300	Stabilizing Load
Power back fed to Kahe from Waiau	1417	14:17 Kahe-Wahiawa line energized
Startup power available to AES and H-POWER	1438	14:38 Kahe-CEIP 2 line energized
Kahe Power Plant & Leeward Coasts, Honouliuli WWTP, Waipahu, Waikele, Mililani Mauka	1500	Stabilizing Load
Startup power available to Kalaeloa and Tesoro	1508	15:08 AES-Kalaeloa line energized
Kahe-Waiau 138 kV ring complete	1558	15:58 Waiau-Ewa Nui 1 & 2 energized
Malakole, Kunia, Village Park, Fort Weaver, Mililani	1600	Restoring Load
Startup power available to Honolulu Power Plant	1713	17:13 Honolulu bus energized
Wahiawa, Waialua, Pearl Harbor, Hickam, and Honolulu International Airport	1730	Restoring Load
Kapolei, Makalapa, Keehi, Sand Island WWTF, Iwilei, Downtown Networks	1830	Restoring Load
Ewa Beach, Waipio, Kailua, Enchanted Lakes, Olomana, Piikoi, Kapahulu	2000	Restoring Load
Remaining Pearl City, Aiea, Kaneohe Marine Base	2100	Restoring Load
Kalihi, Makiki, Kapahulu, portions of Waikiki	2115	Restoring Load
Waikiki, Ala Moana, Aikahi, Kalama, Waimea, Kuilima	2200	Restoring Load
Kakaako, Kewalo, McCully, Manoa, East Honolulu, and parts of Windward coast	2330	Restoring Load
Portions of Kailua, Kaneohe, Pali, Pohakupu, Waimanalo, Kahaluu & Kapalama	0030	Restoring Load
Parts of Central Oahu, Kailua, Lanikai, and Mapunapuna	0101	Restoring Load
Remaining areas: Liliha, Nuuanu, Punchbowl, Pauoa, Makiki, Moilili, Kaimuki, Kailua, Kaneohe, Waihee, Kunia, Waipahu, Waiawa	0155	Restoring Load

Restoration Activities at the Power Plants

As each unit tripped off line, the operators secured the unit, inspected for damage and prepared for re-start.

The decision to simultaneously attempt black start at both Kahe and Waiau was made early by the Manager of System Operation and Manager of Power Supply Operations and Maintenance in consultation with the Incident Commander and the Vice President of Power Supply, since the seismic activity caused concern for the physical condition of the plant equipment. This decision proved to be very wise, as equipment problems slowed black start at both plants. With both plants black starting, the time delay resulting from equipment troubleshooting and inadvertent trips for getting a unit on line was reduced to about one and a half hours (K3 expected on the bus at about 1030 hours versus W6 on the bus at 1154 hours).

Kahe

The Kahe black start generators are rated to be able to start either K1 or K2 and K3 or K4. The following information is based on the Kahe sequence of events report and operator interviews. During the black start process communications were taking place between the COs in the three control rooms, the JCOs and EOs configuring the auxiliary buses and the Shift Supervisor and UO working with the black start generators. In addition, there were constant communications with the Dispatch Center. The decision was made at about 0730 hours to start K1 and the process was started to configure the auxiliary buses. The UO and Shift Supervisor checked and started the black start generators. The UO reported that his previous experience had been to start the black start units and synchronize them with the grid. Consequently, as they first began to load the black start units they remained connected to the grid, tripped on overload and went to idle. The UO then operated breakers 401 and 402 to isolate the units from the grid. On the second attempt, the units tripped on undervoltage because units K1 to K4 were still connected to the startup transformer, and the combined load was too much for the black start generators. The auxiliaries for K1 to K4 were isolated and another restart attempted. This attempt tripped on reverse power.

When the operators encountered trouble loading up the Kahe black starts to K1-2 due to the previously mentioned connections to the auxiliaries, they aborted that plan to restart K1 and switched to connecting the black starts to K3-4 in order to black start K3. About 0830 hours, K3-4 as well as K1-2 and were reported to have received power from the black starts, though at the time, only K1's and K3's auxiliaries were drawing power. The Kahe staff made the decision to black start K1 in parallel with K3. The K3 boiler purge was taking more time than anticipated due to problems with the purge time relay and maintenance was called to troubleshoot the problem which delayed the start of K3. About 1040 hours, K1 was found to have a severe leak of the air injector condenser cover gasket. Again, startup of K1 was aborted and shifted to K2.

K3 corrected the purge system problem and the boiler was purged and had fires in, but the fires were pulled out to avoid exceeding environmental opacity limits at about 1055 hours. K3 had fires in without opacity problems by 1117 hours. At this time the K2 boiler was purging but some auxiliaries were left on K1 from the previous start attempt. The combination of auxiliaries for K1, K2 and K3 overloaded the black start generators and they tripped at about 1119 hours. Because K3 had fires in at the time of the black start trip it required time to purge the boiler and the drum pressure dropped too low for a quick restart attempt. The black start generators were restarted and startup was then focused on K2. During the K2 start process, W6 came on line and began to provide auxiliary power to Kahe. K2 was the first Kahe unit on line and was connected to the bus at 1439 hours. Despite the delay at Kahe, these events did not significantly delay the start of system restoration because of the parallel startup activities occurring at Waiau power plant.

Waiau

The steps required to black start the W5 or W6 units are outlined in the Waiau Station "Simulated Black Plant" Shift Supervisors' "Set Up" Checklist document. The Waiau black start combustion turbine (Solar CT) is configured to start W5 or W6 steam units at reduced boiler drum pressure through the use of its emergency boiler feed pump, which is smaller than the normal boiler feed pump. Because of its smaller size, the emergency boiler feed pump requires lower starting boiler pressure, and thus a longer and more protracted startup process. At 0755 hours, the Waiau staff began planning for the black start operation and started to configure the plant auxiliary buses. On October 15, W6 was designated for black start since it was in the startup process at the time of the blackout and had the most appropriate (lower) boiler drum pressure. W5 was up to full boiler pressure when it tripped and would take much longer to reduce the boiler pressure to allow black start.

At 0940 hours the Solar CT was started and the W6 auxiliary bus energized. Fuel oil flow indication problems with the Fuel Oil Supply Coriolis meter were encountered during the W6 startup and a switch to the backup Fuel Oil Supply Area meter was considered. Other problems were experienced with the Feedwater Bypass valve which required a short time to fix.

The W6 boiler tripped at about 1037 hours while staff were troubleshooting a loss of UPS power to the W5 operator consoles, which also blacked out the W6 operator consoles. At this point, work on the W5 DCS was halted until W6 was brought on line. The restart of W6 was delayed about 30 minutes to purge and restart. At 1053 hours fires were in W6 and it was connected to the dead bus at 1154 hours. Local load was then connected to stabilize the unit and the Waiau startup transformer was energized to supply power to the other Waiau units.

Other issues at Waiau during the system restart were that during the power outage, the W9 battery was drained by a DC lube oil pump that was running. The drained battery also powered the W9 distributed control system (DCS) which could not operate until power was restored. W10 failed to fire during initial startup because there was no instrument air to the fuel forwarding control valve. Instrument air compressors were secured to unload the Solar CT during black start and manual switch-over to nitrogen bottles (as a substitute for instrument air) was not executed.

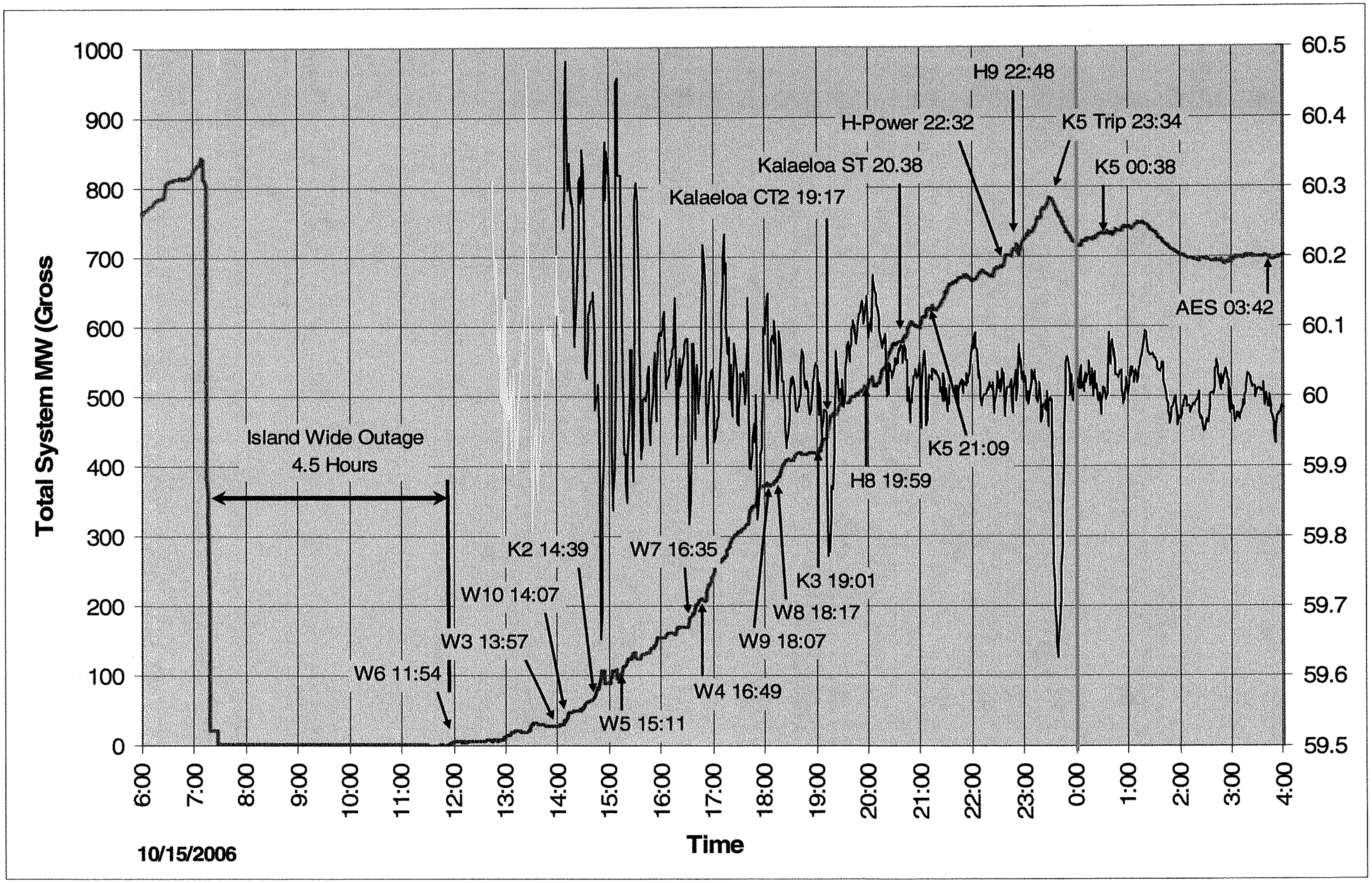

Figure 4: Generation Restoration Megawatts and Frequency versus Time

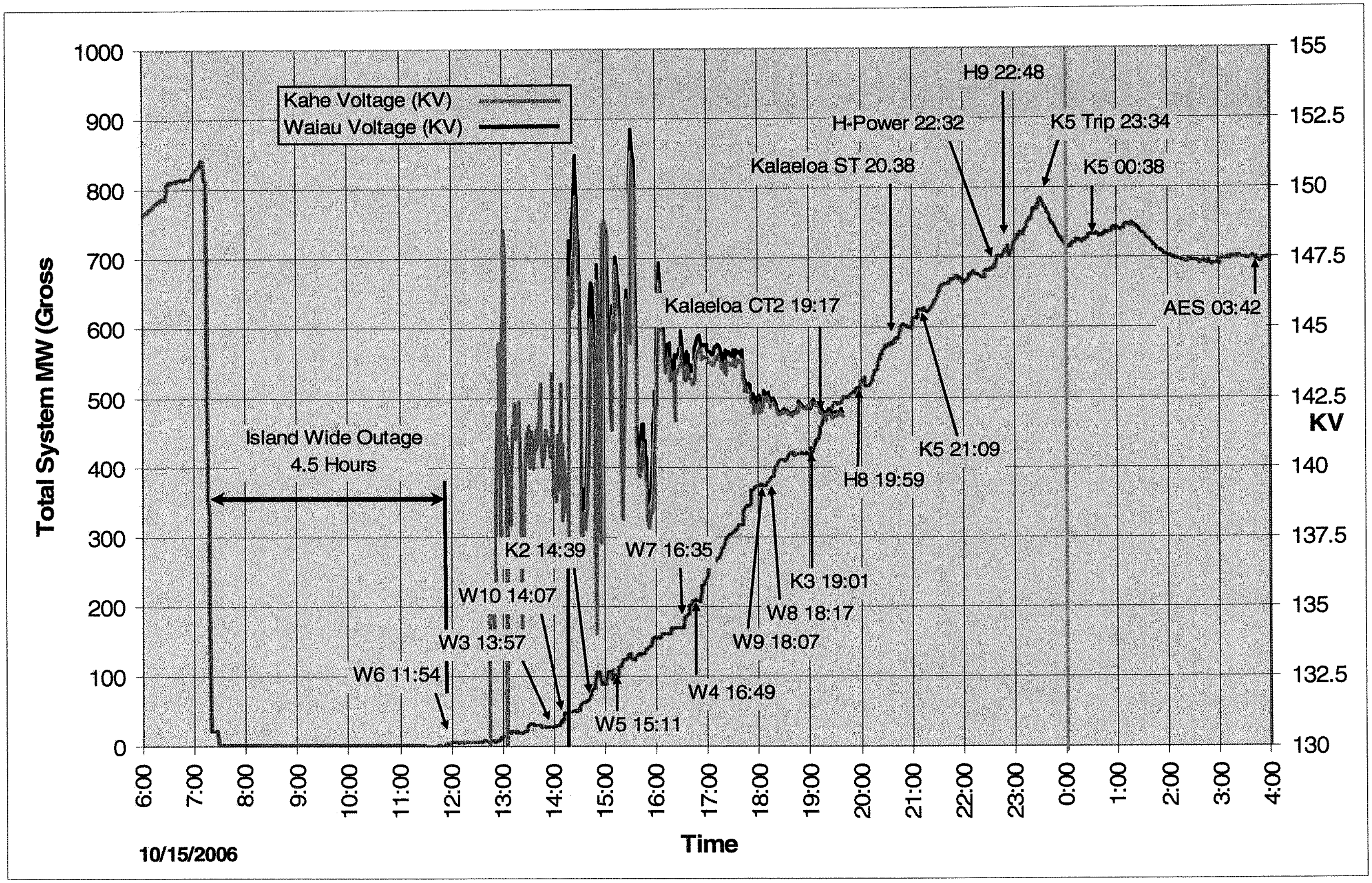

Figure 5: Generation Restoration Megawatts and Bus Voltage versus Time

3 Evaluation

3.1 Generation Capacity

3.1.1 Oahu Generating Fleet

Approximately 1,737 MW of generating capacity is currently installed on the island of Oahu, with 1278 MW owned and operated by HECO, and 459 MW by Independent Power Producers (IPPs). The HECO plant capacity is summarized in Table 3 and the IPP plants in Table 4.

The HECO generating equipment is notable for:

- The high proportion (91%) of generation from steam boiler/turbine plant equipment
- The considerable age of this fleet of steam units.
- The relatively high-energy steam (1,815 pounds per square inch absolute (psia)/1000° F/1,000° F, reheat) operating conditions employed for 75% of the steam plant capacity.

The relatively high steam conditions should confer good thermal efficiencies which equates to economic generation. These steam conditions and the ages of the plant can be expected to represent operational challenges, especially for rapid load changes and quick starting. Steam plants, and in particular, older designs, generally have difficulty remaining in service following sudden, large losses of load (load rejection) unless they have special provisions, such as large capacity steam bypass systems. Sudden large load reductions can take boiler operating parameters to the point where control equipment intervenes to protect plant from damage, and automatically "trips" the unit, to take it out of service.

Steam plant units are always relatively complex and slow to start or to re-start after a sudden trip. In general, the difficulties which steam plant equipment has in coping with major load changes and the complexity of starting tend to increase with the age of the design of the plant and with higher operating conditions.

3.1.2 Possible Role of Combustion Turbines and Diesel Engines in Blackouts

Combustion turbines are essentially simpler technology than steam units and, at least in the case of more modern units, are likely to be able to respond to rapid changes in electrical load. There is a relatively small amount of modern combustion turbine capacity on Oahu. We have, however, particularly noted the combined cycle "block" of two gas turbines and one steam turbine operated by Kalaeloa Partnership LLC. One might expect that the Kalaeloa combustion turbines would be able to tolerate a major loss of off-site load without "tripping" or automatically shutting down, and this was indeed the experience during the October 15, 2006 incident. On October 15, Kalaeloa Combustion Turbine #1 was out-of-service for maintenance. Kalaeloa Combustion Turbine #2, which was on line on October 15, tripped to its house load due to underfrequency. The Kalaeloa combustion turbine would have been available to export power to re-energize the transmission system. However, we understand that, as is quite normal practice to ensure safety of the HECO transmission system, the 138kV breakers and protection system are configured to prevent back-energization of a "dead" HECO connection by the Kalaeloa units.

POWER appreciates that an engineering effort would be necessary to reconfigure the switchgear controls and protection of the Kalaeloa combined cycle block, to permit it to re-energize the HECO 138kV system in the event of the HECO connection being "blacked out". However, the capital cost of new equipment to convert the connection to the Kalaeloa Partnership generation to a valuable resource would be modest, compared with other schemes to add a significant black start capability to the HECO system. We acknowledge that the Kalaeloa plant does not itself have a black start capability, but, by its nature as a HECO dispatched baseload unit, it is in operation for most of the hours in each year. Provided that it is equipped with low frequency tripping protection to separate it from a HECO system in terminal frequency decline, the Kalaeloa plant would normally be available to provide a restarting resource.

We would expect that the manufacturer of modern combustion turbines of this general type would routinely include, in the controls of the machines, 'governor' and Automatic Voltage Regulator functions, such that the Kalaeloa combustion turbines would be able to satisfactorily regulate the frequency and voltage of an 'island' of load during the re-starting of 'black' transmission circuits.

A significant investigation would be needed, no doubt covering a range of engineering, design, operational, and permitting issues, and discussions would be needed with the owners of the Kalaeloa units, in regard to their operational objectives and costs. We are however of the view that such an investigation would be worthwhile, to determine whether the Kalaeloa combustion turbines could be a added to HECO's armory for dealing with serious transmission system upsets, at a reasonable cost, and in a practical and safe manner.

We note that the HECO "Frame 7B" gas turbines which comprise Waiau units 9 and 10 could also provide power to restart a "black" transmission system, but we also understand that these units do not themselves have a black start capability, and they typically operate for approximately 1,000-1,500 hours per year. It might be worthwhile to consider reconfiguring switchgear controls and protection to also allow the Waiau 9 and 10 units to re-energize "black" bus bars. However, we do note that the chances of this being of value might be of the order of 1,500/8,766 x 100 =

17%, since the units run typically for only 1,500 hours in the 8,766 hours in a year and only upon instances when during a system disturbance, W9 and W10 can successfully island. W9 and W10 must operate with a minimum of 5 MW of load for each machine to prevent violating the air quality permit.

We appreciate that this very simple calculation assumes that the likelihood of a system blackout is the same whether the system is highly loaded or not, and that the two machines run for the same 1,500 hours in each year. Nevertheless, the 17% result is low and we would contend that the calculation is illustrative. The long term value of investment in this upgrade will be diminished by construction of the planned new Campbell Industrial Park ("CIP") 100 MW CT in 2009, which will have black start capability.

The distributed generation (DG) diesel units at three HECO substations were available on October 15 and are designed to provide peaking power. They are connected to 12 kV feeders and the design of the connection, the fact that these DGs are connected to the grid through feeders that also contain loads as well, and relaying and controls schemes do not allow these units to isolate and back-feed to the 138 kV system to be used for black start power.

3.1.3 Operational Generating Capacity on October 15

The system conditions on the morning of October 15 are discussed in sub-Section 2.2 of this report, and the status of the generating units, as of 0708 hours that morning, are shown in Table 1. The capacity of plant operating at that time was 1,111 MW, substantially in excess of the consumers' demand of 837 MW. Indeed, the 275 MW of excess operating capacity, over and above the demand, was substantially greater than the 180 MW capacity of the largest unit operating. Thus, if the largest unit (on the morning of October 15th AES was operating at approximately 180 MW and represented the most heavily loaded unit on the system at the time) had suddenly and unexpectedly tripped and ceased to supply power, the remaining operating capacity could have met the shortfall.

Considering the installed and operationally-available generating capacity and the consumer demands on the island of Oahu on the morning of October 15, 2006, the black-out of the system was not connected with any shortcomings in the HECO processes for the long-term planning of generating capacity, or the timing of the startup of cycling units, or indeed, the selection of generating units to operate that morning. The events which followed the earthquake were not a reflection of any failure in the process for planning additions to the generating capacity on the island.

Table 3 HECO Generating Units							
				Turbine Inlet Steam		Condenser Vacuum	Gross Capacity
Unit	**Service Date**	**Type**	**Fuel**	**Pressure PSIA**	**Temp. Deg. F**	**Inches Hg**	**MW**
Honolulu 8	1954	Steam	Low sulphur fuel oil	1265	950	2.0	56
Honolulu 9	1957	Steam	Low sulphur fuel oil	1265	950	2.0	57
Kahe 1	1963	Reheat steam	Low sulphur fuel oil	1815	1000/1000	2.0	92
Kahe 2	1964	Reheat steam	Low sulphur fuel oil	1815	1000/1000	2.0	89
Kahe 3	1970	Reheat steam	Low sulphur fuel oil	1815	1000/1000	2.0	92
Kahe 4	1972	Reheat steam	Low sulphur fuel oil	1815	1000/1000	2.0	93
Kahe 5	1974	Reheat steam	Low sulphur fuel oil	1815	1000/1000	2.0	142
Kahe 6	1981	Reheat steam	Low sulphur fuel oil	1815	1000/1000	2.0	142
Waiau 3	1947	Steam	Low sulphur fuel oil	865	900	2.0	49
Waiau 4	1950	Steam	Low sulphur fuel oil	865	900	2.0	49
Waiau 5	1959	Steam	Low sulphur fuel oil	1265	950	2.0	57
Waiau 6	1961	Steam	Low sulphur fuel oil	1265	950	2.0	56
Waiau 7	1966	Reheat steam	Low sulphur fuel oil	1815	1000/1000	2.0	92
Waiau 8	1968	Reheat steam	Low sulphur fuel oil	1815	1000/1000	2.0	94
Waiau 9	1973	Combustion turbine – GE Frame 7B	Diesel	N/A	N/A	N/A	53
Waiau 10	1973	Combustion turbine – GE Frame 7B	Diesel	N/A	N/A	N/A	50
Distributed Generation	2005	Diesels	Diesel	N/A	N/A	N/A	15

Table 4 Non-HECO Oahu Generating Units			
Unit	**Type**	**Fuel**	**Gross MW**
AES	Steam boiler/turbine	Coal	180
H-Power	Steam boiler/turbine	Municipal solid waste	46
Kalaeloa Partners Cogeneration	ABB Type 11 NM - based 2 + 1 combined cycle	Low sulphur fuel oil/diesel	208

3.2 Outage

3.2.1 Operator Trips of Turbine-Generators

The K3-4 CO only had one turbine operating at the time of the earthquake. Based on alarms and previous experience, he believed he had a severe turbine water induction problem causing the vibration and tripped the turbine to minimize damage. The K3 CO also reported that he understood that there was sufficient excess spinning reserve and quick load pickup available to support the load dropped by K3.

The K3 CO and JCO reported several feedwater Heater High Level alarms in conjunction with the significant vibration of the control room and plant. The turbine is located approximately 50-75 feet from the control room and on the same floor, but out of view of the CO. The CO reported that he was aware of a water induction incident on W8 in which a feedwater heater tube leak backed up into the turbine and caused significant damage to the turbine.

The K1 through K6 are re-heat units. This means that the exhaust from the high pressure turbine section is reheated in the boiler before entering the intermediate pressure turbine section for overall cycle efficiency. The feedwater heaters are designed to preheat the boiler water before it enters the boiler using steam extracted at different points on the high pressure, intermediate pressure and low pressure turbine sections. A serious leak will cause the higher pressure feedwater to back into the turbine, causing a thermal gradient that will bow the turbine and cause serious vibration due to eccentricity resulting from the bowing and unbalance caused by rotor contact with stationary parts.

On October 15, the CO believed this was the case and tripped K3 from about 50 MW of generation. The impact of the trip reduced system frequency by about 0.4 Hz to 59.6 Hz.

The H8-9 CO only had H8 operating at the time of the earthquake, H8. H9 was scheduled for maintenance the next morning, and thus was not scheduled to run on Sunday. H8 was still ramping up to its minimum load at the time of the earthquake. After the first tremor the JCO and UO came into the control room. The CO believed he had severe turbine vibration and a potential safety problem, so he tripped the unit. The CO had been present in 1998 when H8 fractured a low pressure turbine blade, resulting in severe vibrations. H8 was just ramping up into production and the CO also expected that the loss of the approximately 20 MW could be absorbed by the other units. After H8 tripped, the system frequency remained at about 59.6 Hz.

Operators at the other plants either a) did not get alarms triggered by the earthquake or b) had two turbines running and therefore their situations were different from K3 and H8. In the process of determining which turbine was vibrating the other operators quickly concluded that the turbines were not the cause of the shaking they felt.

Turbine Vibration Detection

We note that most of the HECO steam turbine fleet has been retrofitted at various times with modern turbine supervisory systems (manufactured by Bently Nevada, and others). Vibration and shaft eccentricity measurement technology has advanced very significantly from the equipment which was available when the HECO turbines were first designed and built. No turbine generator set vibration alarms were recorded during the October 15 earthquake event, despite the tremors that were sufficiently strong to shake the buildings and cause concern, or in some cases, nervousness, on the part of the operating staff. This is not particularly surprising and, in fact, is indicative of the sophistication of modern supervisory monitoring equipment and its ability to discriminate events relevant to the health of a turbine generator set.

The turbine supervisory equipment is intended to detect shaft out-of-balance or eccentricity on the turbine, generator and exciter shafts, and to protect these shafts from damage by providing condition monitoring data relevant to the health of the generator set. The supervisory gear is accordingly concerned with relative shaft-to-bearing and shaft-to-casing motions and vibrations and eccentricities. These differ distinctly from earthquake tremors, being sustained in duration, and at the frequencies of shaft rotation and its higher harmonics.

Earthquake Influence

From the operator interviews, it is evident that the staff at the power plants experienced strong sensations of movement and/or vibrations at the times of the earthquake tremors, but most did not immediately realize that they were experiencing an earthquake.

As was typical of power plants of the sizes and types which make up the bulk of the HECO fleet, the control rooms are positioned on the same level as the turbine generator operating floors. They are thus relatively high above ground level and carried in the steel frame structures of the power houses. The ground accelerations of an earthquake can therefore be expected to result in significant and disorientating accelerations and movement for operators in the control rooms, given the relatively flexible steel frame structures. In the quite exceptional circumstances of the earthquake, and with the proximity to the turbines and the usual noise levels around the turbines, we do not find it surprising that the operators failed to comprehend that they were experiencing an earthquake, and all initially suspected severe turbine vibrations.

It appears that the K3 and H8 operators acted to trip their units based on reasonable judgment and experience. With only one unit operating, they had reasonable expectations that turbine was vibrating rather than that they were experiencing an earthquake. They also had sound reason to believe that the loss of the unit's generation output would be well within the system spinning reserve and quick load pickup capabilities.

3.2.2 E.H. Low Fluid Level Lockout Trip of Kahe 5 and Kahe 6

The loss of generation by K5 and K6 between 0710 hours and 0715 hours on October 15 resulted from a chain of events initiated by the apparent detection of "low-low" levels in the reservoirs for the hydraulic fluid used to control the steam turbine governor valves. The turbine steam control at the time of the event incorporated an 86 LFT "Lockout" feature that prevented the operation of the hydraulic pump motors when "low-low" hydraulic fluid level was detected in the reservoir.

Interviews with the K5-6 operators indicated that they received a "Low Fluid Level Lockout" alarm on both units along with many other alarms at the time of the earthquake. This indicates that the 86 LFT "E.H. Reservoir Low Fluid Level Trip" lockout relay operated. This relay prevents the recharge of the hydraulic system pressure until an operator checks the system and hand resets the lockout. This fluid level is measured in the low pressure reservoir of the E.H. Governor system that controls the power output of the steam turbine.

Following the earthquake, the operators were experiencing the stress of the earthquake event itself, plus being assailed by a plethora of alarms. In addition, they also had to respond to the sudden load changes due to the K3 and H8 operator-initiated trips. The sudden load pickup by K5 and K6 required the COs and JCOs to adjust burners and start standby condensate pumps to maintain the boiler pressure and sustain the new load level. Under these conditions they did not note and appreciate the particular significance of the "Low Fluid Level Lockout" indications in the annunciator panel alarm windows while the units continued to run and even pick up load, and did not have time to take the action of checking the system and hand resetting the lockouts. The K5-6 CO noted that his experience had been that operations of other "Lockout" relays usually immediately tripped the unit, which is not part of the lockout design for the E.H. System 86 LFT.

The E.H. system uses an electronic controller and high pressure hydraulic fluid to actuate the valve controlling the amount of steam flowing into the turbine. This valve is opened by hydraulic fluid pressure and closed by spring pressure. The hydraulic fluid is pumped from a low pressure reservoir into a header that contains high pressure accumulator tanks with typical pressure ranging from 1,500 pounds per square inch gauge (psig) to 1,800 psig. During normal operation, the fluid from the accumulator tanks bleed off through the system valves, returning to the low pressure reservoir. Depending on the system conditions and unit, it can take two to six minutes to bleed down below operating pressure. When the hydraulic system pressure drops to 1,500 psig, pumps cycle and recharge the accumulator tanks. If the system is not recharged and the hydraulic system pressure falls below the counter pressure of the steam valve springs, the valve controlling the steam flow to the turbine begins to close. As the hydraulic pressure continues to decrease, over a period of 15 to 30 seconds, the valve springs continue to close shutting off the power output of the turbine-generator set as shown in Figure 3. If the fluid level in the reservoir drops below a preset margin, the low level alarm signals the operators that there may be a problem. If the reservoir fluid falls to a "low-low" level then the "Low Fluid Level Lockout" 86 LFT unit trips to protect the pumps and signify a loss of hydraulic fluid, resulting in turbine shutdown after two to six minutes. The reason that K6 stayed on line significantly longer than K5 is that it was designed with four accumulator tanks whereas K5 only has two. K6 was built several years after K5.

POWER was advised that, after the incident, the levels in the hydraulic reservoirs for the two units were visually checked and found to be normal. Based on this observation, two alternative mechanisms for the "low-low" level indications for the two units are evident to us.

- o Although significant fluid was apparently not lost, initially we thought it might be possible for the earthquake tremors to cause wave actions in the reservoirs, and thereby fleetingly carry the levels below the "low-low" switches. We have used the dimensions of the reservoirs provided by HECO to carry out a simple form of analysis to attempt to determine whether some form of wave pattern could produce the necessary reductions in the levels local to switches. The reservoirs are normally 2/3 full and the "low-low" level pump trip occurs at 7-7/8 inches, approximately 1/5 of the reservoir capacity. Our conclusion is that the dimensions of the reservoirs and the amounts of fluid in them were such that voids deep enough to trigger the "low-low" switch and 86 LFT resulting from waves action are improbable.

- o Alternatively, the "low-low" level switches could have given false indications. We can appreciate how the type of switch employed for these level delegations could give false indications, in the event of the quite exceptional types of accelerations experienced during the shaking. In investigating the E.H. Governor Systems at Kahe, it was determined that they use a mercury displacer type liquid level switch (Westinghouse instrument number 71FL2). Mercury type switches utilize a liquid (mercury) medium to complete the electrical contact circuit within a glass capsule. Normally, controlled tilting of the capsule accomplishes this closing or opening of the circuit. The vendor information does not specifically describe the effects of vibration on this A Series level switch, but does state that their E and T series models are more vibration resistant. This A Series type of switch was widely used in the industry at the time that the Kahe plants were designed and constructed. During seismic shaking it would be possible for the mercury bubble to have sloshed across the contacts to trigger the alarm and 86 LFT trip.

The significance of a "Lockout" relay in the utility industry is that it enforces the standard requirement for the operators to inspect the condition of the equipment and verify the underlying cause of the relay operation. Once the fault is located and repaired or the system is inspected and or tested and found to be in operating condition, the "lockout" relay is hand reset and the system restored to operational status. Inspection of the E.H. system requires that the JCO or the EO go to the second story (one flight of stairs for each), walk about 70 feet and inspect the E.H. reservoir, check fluid level, inspect the system integrity to the turbine, and determine the cause for the alarm. In the case of October 15, 2006, with both K5 and K6 "Low Fluid Level Lockout" alarms tripped, this activity was required for both units in addition to activities to control boiler operation to maintain the increased load levels. Had the Kahe 5-6 operators recognized the significance of the "Low Fluid Level Lockout" alarm and that the E.H. Lockout had tripped, it is very doubtful that they could have performed a proper inspection and determined that the "Low Fluid Level Lockout" trip was due to a false indication by a mercury switch caused by the seismic shaking in the three to six minutes available before Kahe 5 and Kahe 6 lost power.

One key finding from this evaluation is that the Kahe Plant units K3, K4, K5, and K6 have mercury switches in various level control and monitoring systems (including the E.H. systems) that could be susceptible to false operation during a seismic event. The alarms of the feedwater Heater High Level indicators significantly added to the number of alarms that the COs, JCOs, EOs and UOs had to interpret and consider in their decision processes during the event.

3.2.3 Dispatch Center Event Response

After the initial tremor, it was clear to Dispatch Center personnel that the system had experienced an earthquake. K3 and H8 were tripped by the operators and the LD announced that the system had experienced an earthquake. The EMS began logging multiple alarms. The LD called for the start of the Waiau CTs and initiated the start of the distributed diesels, but the system collapsed before these units could come on line. When K5 power output dropped, many additional alarms began to register and it became difficult to assess the system condition from the alarms log. The SLD began to concentrate on the AGC screen information showing generation, excess spinning reserve, quick load pickup, and the system frequency and voltage. From the recent System Dynamics training, the SLD suspected they were at risk of losing the system and prepared to initiate manual load shed. When K6 lost power and the frequency dropped, the SLD began to shed load as fast as possible to augment the automatic load shed. The system frequency was not recovering fast enough and the K1-2 control operator made the decision to separate from the system due to the low frequency situation.

At this point, the Waiau units were in complete overload distress and tripped. K1 held on to local load for another eight minutes but eventually tripped. Over the course of the event, the dispatch personnel applied applicable training and experience to do their best to recover from the loss of eight generation units over the course of 5.5 minutes.

During the time of the event, it appears that the SLD and LD took appropriate actions, using previous training and experience to quickly and correctly determine that after the loss of power from K3 and H8 that such loss would affect the system spinning reserve and called for startup of the Waiau CTs and the substation DGs to make up the lost reserve. When K6 lost power the SLD quickly realized that the system was in jeopardy and initiated manual load shed actions to try to salvage a portion of the system to provide restart power. If one main generator can stay on line, it can be used to reduce the time required to restart the other plants as they will operate in the normal mode rather than black start mode. POWER's only concern with their actions is with respect to the extended low frequency operation as discussed below, although their action were within the HECO ODPM guidelines as noted below.

3.2.4 Low Frequency Operation

Generating units synchronized to the HECO system between 0708 hours and 0727 hours on the morning of October 15, 2006 were constrained to operate at significantly below their nominal design frequency of 60 Hz and rotational speed of 3600 rev/min. The action of turbine governors would most likely have resulted in the turbines operating at full load, or with their steam inlet valves wide open, for at least part of the period of low frequency operation.

It has long been typical industry practice to equip turbine generator sets with provisions to automatically disconnect from the transmission system, and/or "trip" the turbine, to avoid operation at frequencies which could be damaging to the turbine. As noted previously, the AES and H-Power steam units and the other IPP units employ low frequency operation protection. In POWER's experience, the generator manufacturer provides a Time-Frequency turbine damage curve that is used to set the low frequency protective relays.

The HECO Operations Manual – Section IV, Severe System Frequency Depression allows the COs to decide whether to island the plant if the frequency decays below 57 Hz, but advises "Extreme care and judgment must be exercised in arriving at this decision." The reason for this care in this decision is that islanding is likely to result in stress on other units connected to the system. The time line shows that the steam turbines operated below 57 Hz for about 3 minutes before the Station Superintendent and CO at K1-2 decided to separate. Over the Hotline, power plant operators were asked by the LD to try to hold on to the system.

Our principal concern relates to the long moving blades in the Low Pressure (LP) cylinders of W5, W7, and W8, which we understand have blades of around 16 inch length. It would seem that W5, W7 and W8 operated for some 4 minutes at frequencies in the 58.5 Hz to 52.5 Hz range, and may have been down to perhaps 51.1 Hz. We also have secondary concerns for potential thermal and mechanical stresses on the generator. We note that at this time we do not have specific information on the low frequency capabilities of the HECO turbine-generator units and have not made a judgment that they were operated below their safe frequency range.

In order to install a turbine low-load tripping scheme on the HECO turbines-generator sets, and in order to consider how the system-wide load shedding scheme might be used to avoid such tripping, it would be necessary to determine the safe, full load, operating frequency range, for each of HECO's generating sets. We accept that for the HECO steam turbine generation fleet, this may not be easy due to the age of the turbines. We nevertheless believe that it would be practical to establish safe operating frequencies, and durations for operation at reduced frequencies, for the last row blades of the turbines. (In this connection, typical industry practice is reflected in the US Institution of Electrical and Electronic Engineers Standard C37.106-2003, entitled "Guide for Abnormal Frequency Protection for Power Generating Plant").

General Turbine Low Frequency Operation Background

A turbine's failure mechanism is rooted in unavoidable tendency of the blades to vibrate and the excitation of that vibration by the turbine rotation. The blades are inherently relatively flexible and accordingly pass through several different vibrational modes between standstill and the 60 Hz synchronous speed of 3600 rev/minute. The designer tunes the blade design so that there are no vibrational modes which can be significantly excited by turbine rotation at frequencies at which the turbine can normally be expected to operate at full load. A range of 58 Hz to 60.5 Hz has been a typical design objective.

In the event that a turbine operates with significant load at a frequency which results in excitation of blade vibrational resonance, there is a risk that the stresses in the blade material will induce fatigue damage. This can then be followed by crack initiation, usually at the location of a "stress raiser". (A typical point of crack initiation is at the inboard end of recesses, machined in the blade aero-foils to accept water droplet erosion shields.)

Once a fatigue crack initiates, the crack propagation depends on the stress in the remaining material of the aerofoil cross-section of the blade. If those stresses become sufficiently high, the crack ultimately grows rapidly and the outboard section of the blade breaks off, and severe out-of-balance vibration of the turbine shaft follows. The centrifugal loads in the long last row blades are significant and the section of the blades which breaks away becomes a missile which can do further damage within the turbine and condenser. Punctured condenser tubes are a common form of secondary damage. Such damage can result in a lengthy unit outage.

3.2.5 Load Shed

The indications are that the automatic load shed schemes operated mostly as planned. Automatic load shed combined with manual load shed in this instance, were unable to arrest the frequency decay due to the loss of H-Power, Kalaeloa and AES in addition to the four HECO units. Mathematically, with loss of K3, H8, and K5 power plants, and considering the approximately 25

MW of load shed planned with the "Kicker Block", the system would have had about 50 MW of reserve remaining. The subsequent loss of K6 left the system with about a 90 MW generation deficit. Load shed blocks 2 through 5 have frequency set points, without time delays, below the frequency set points of the AES and H-Power power plants. However, the underfrequency trip set points for AES and H-Power have time delays before breaker trip action is initiated. In this case, operation of load shed blocks 2 through 5 happened in very close proximity in time to the trips of H-Power, Kalaeloa CT-2 and AES by their respective underfrequency relays. At this point, the frequency dived, along with the 138 kV bus voltages, initiating trip of an undervoltage load shed block. Operation of the undervoltage load shed block along with manual load shed by the SLD recovered the frequency to about 55.5 Hz but then frequency declined again as W8 power output reduced. The SLD continued manual load shed which recovered the frequency to about 56.7 Hz when the K1-2 operators made the decision to island with local load. At this point, the remaining connected system with just the W5, W7 and W8 units could not hold the system load and provide time for additional manual load shed.

We must note that there are a number of underfrequency relays that did not give a clear indication that they operated, because they either did not provide a target indicating it tripped or they exhausted their event report capacity and overwrote the initial records. HECO maintenance personnel tested the relays that did not target and found that the majority of them operated properly. Two breakers were noted to not have tripped during the automatic load shed sequence. It appears from the frequency recovery that the automatic load shed scheme operated as planned for the most part. We do note that the time-delayed underfrequency trip settings for H-Power and AES as established pursuant to administrative letters between the IPP and HECO are above or at the trip points of load shed blocks 1 through 5, which have no time delays. And even though these IPP underfrequency set points were considered in HECO's previous underfrequency load shed studies, this leaves a potential window where slow frequency decay, such as occurred during this event, can allow the two IPPs to trip before the majority of the automatic load shed occurs.

3.3 Restoration

3.3.1 Black Start

A critical and prudent decision was made at about 0809 hours on October 15 to black start Kahe and Waiau power plants in parallel. Plant personnel formulated the black start plans and identified the units to be started first. Under the circumstances, extra caution was required to assess equipment possibly damaged by the earthquake that could endanger additional equipment or personnel safety during operation. Initial expectations communicated to the SLD were that K3 would be the first plant on line at about 1030 hours. W6 was actually the first unit on the bus at 1154 hours. The first Kahe unit on the bus was K2 at 1439 hours.

As the plant personnel at Kahe performed the black start procedures, they encountered several procedural and equipment problems, previously noted, that required trouble shooting and reassessment of the plan. Initial setbacks were encountered by the UO and Shift Supervisor getting the black start configured properly to supply power to only the required plant auxiliaries. The start sequence changed from K1 to K3, then K1 and K3 in parallel, and then K2 in place of K1. Status of units and auxiliaries was apparently not well communicated between the control rooms. The modifications to the plan and trouble shooting resulted in time delays in getting the Kahe units started. The progressing modifications of the plan to meet changing circumstances resulted in the inadvertent configuration of the auxiliary bus leading to a trip of the black start diesels that resulted in a further delay. The Kahe plant is a baseload plant and the units are taken off line infrequently. Tripping the units at full load in addition to the seismic activity significantly stresses equipment beyond the normal daily activities and we would expect a certain amount of equipment failure.

At Waiau, the black start procedure also encountered equipment malfunctions and the operators had to restart W6 due to a trip when the UPS bypass was closed between W5 and W6 DCS during troubleshooting. It took about 2.5 hours to configure the auxiliaries and Solar CT along with solving the issues with the fuel oil supply and the feedwater bypass valve and get fires in W6. The inadvertent trip of W6 resulted in a delay of about 30 minutes until W6 had fires back in. The November 14, 2006 generation log indicates that W6 normally takes about 35 minutes from fires in to connecting to the bus. The black start times were about 30 minutes longer. These units often cycle daily and the normal equipment is regularly exercised in the normal shutdown and startup process. The equipment delays, trouble shooting and re-start of W6 delayed the Waiau start by about 1 hour. It should be noted that black start training for Waiau is conducted with the black plant boiler drum pressure at near zero (unit is typically returning from an extended outage). Thus, simulation of black plant start does not include the challenge of keeping boiler drum pressure below what is required to start the emergency boiler feed pump once fires are in and operators are lining up the system for water/steam flow. On October 15th, startup time of W6 included time required to let boiler pressure drop low enough to start the emergency boiler feed pump while keeping boiler warm.

The Kahe black start sequence did not operate as smoothly as in practice. A smaller part of this was due to inexperience of the operators that were involved in disconnecting the diesels from the grid and properly configuring the selected steam unit auxiliaries. The larger part was due to encountering equipment problems during the startup of K1 and K3 that resulted in adjustment of the plan to start different units in attempts to minimize the outage duration. The chain of events, including the attempted start of a unit, discovering problems (procedural and equipment), revising the start sequence, and troubleshooting the problems contributed to delays in getting the Kahe units on line. The Waiau black start went much closer to the plan for the W6 unit with a short delay to contend with equipment problems. But we also note that some equipment configuration issues delayed the start of W9 and W10. We also note that black start of the Kahe and Waiau power plants is an activity that has rarely been required, the last time being 15 years ago, so familiarity with the procedures for a significantly complex process can only come through training, rather than developing proficiency by consistent application, and such training is limited by how much can be simulated while the other units are operating.

System black start duration could be considerably shortened if one of the Kalaeloa CTs remain running during an event and can be closed back to the "dead" 138 kV bus providing startup power for the other plants. Also, the CIP CT planned for 2009 will have black start capability and should be able to be on the bus within an hour.

3.3.2 Transmission and Distribution Load Restoration

The transmission and distribution system remained in full service with the exception of the Koolau-Wailupe #1 46 kV line which automatically transferred its load to backup circuits.

The restoration plan developed was based on HECO's past experience with the frequency and voltage stability conditions of the system with only one generator on line and low load, system constraints, black start generator locations and priority loads. We can certainly understand the painstaking steps that had to be taken to restart the entire system from a blackout. Numerous activities were taking place in the power plants as Power Supply personnel prepared to black start generating units at Kahe and a unit at Waiau. Simultaneously, the dispatchers, PTMs and management personnel were preparing the electrical grid for the first unit to come on-line. In addition to preparing the system for restoration, key operations management personnel were developing a sequence for the restoration process. HECO personnel have indicated that during the restoration, the internal HECO communication systems between the Dispatch Center, power plants, and restoration field crews operated adequately and did not hamper restoration.

HECO's practice from experience is that, particularly in the early stages with only one generator on line, load additions must be carefully managed to prevent tripping of the steam generator in the early stages when the plant operators are managing low load levels with the burners and boiler pressure. As additional units are brought on line and the load on the machines increases to near capacity, they are less sensitive to load increases. The generation/load mix was monitored and controlled by the LD and plant operators.

System diagrams and maps were used to track the progress of the restoration. PTMs, C&M crews, and Substation crews were moved in an orderly fashion from one area to another to keep the power restoration constant. The interviews indicate that except for the initial hour after W6 came on line, when they had issues with the load shed relays preventing some breakers from closing, the field crews were ready to close in breakers and were often waiting for the LD to call for closing the breakers. The HECO staff also indicated that the system experienced high voltages as the 138 kV systems were energized to the distribution substations, which required LD and plant operator management, and in some cases intervention, to re-open a circuit. As the restoration effort progressed, the Incident Management Team continued to oversee the critical loads restoration priority, both for HECO's infrastructure and the public's requirements to adapt to sometimes changing priorities as the outage duration lengthened and within the constraints of a partly energized transmission grid. The PTM, C&M crew, and Substation crew dispatch and number of personnel available were adequate and did not delay the power restoration effort.

HECO operated in the public's interest by following a systematic, orderly and methodical approach to add load to the system so that there would be adequate time to stabilize the operation of the generating units, and stabilize frequency and voltage on the grid. If the dispatchers attempted to add larger blocks of load this early in the load restoration process, the likely result would have been much larger frequency and voltage fluctuations as the generating unit attempted to supply power to this load. The control operator would have experienced more difficulties controlling the operating generating units and stabilizing system voltage and frequency. Pickup of larger load blocks could also have resulted in trip of W6 requiring that the whole black start sequence be started over.

While on the discussion of whether or not HECO should have attempted to add load in larger blocks, we believe that HECO personnel were justifiably concerned about the potential impact that the earthquake had on the electrical system. Through our interviews, we gathered information that the load dispatchers as well as the control operators experienced the severe shaking from the earthquake and that at one point the dispatcher did a quick visual check of the control center office to determine if the building had been damaged by the earthquake. This potential damage scenario was mitigated somewhat when the Incident Command Team requested an inspection of the system to determine if damage had been sustained to the transmission system, substations, and power plants.

To provide some idea of the magnitude of the change in load if a 46 kV circuit breaker was used to energize several distribution substations at the same time, it would be equivalent to closing 8 to 12, 12 kV circuit breakers at one time. Keep in mind that as the outage progressed, dispatch personnel became more concerned with the amount of Cold Load Pickup that they would encounter as water heaters and refrigerators were left off for longer periods. Thus, the potential impact of the Cold Load Pickup would significantly change the dynamics of the load restoration if the 46 kV circuit breakers were used to restore load.

3.3.3 HECO, MECO and HELCO Restoration Comparison

At this time, investigations of the outages on the MECO and HELCO systems have not been completed[10]. Based on very preliminary data regarding the outages and historical data provided by the utilities, POWER has formed a preliminary opinion regarding the comparison of the restoration of the three power systems.

Considering the power plants on the three islands, we can understand why re-starting generation on Maui and the island of Hawaii would very likely be much easier and quicker than on Oahu. On these other two islands the generating fleet is dominated by diesel engines and combustion turbines. Steam plant capacity makes up only around 19% of HELCO's generating capacity, and 14% of MECO's. As is described in sub-section 2.2 of this report, HECO has 91% of its generating capacity in its steam plant fleet, most of it old. The generating fleets on the island of Hawaii and on Maui are dominated by diesel engines, as is appropriate given the much smaller sizes of the islands loads. Starting diesel engines, on Maui and the island of Hawaii, could be characterized as needing only minutes for each engine. In addition, the HELCO system managed to maintain an island of generation and load in the Hilo area which negated the need to reconfigure any power plant auxiliaries to allow black start.

[10] The PUC Order directs completion of the HELCO and MECO outage investigations by March 30, 2007.

The generation technologies and the smaller generating units on Maui and island of Hawaii are thus quite different to start and operate from those employed by HECO. By comparison, HECO's steam boiler/turbine units are inherently much slower and can be somewhat temperamental to start and re-load. As noted in section 2.3.2, in the early stages of restoration on the HECO system, great care must be taken to stabilize the system, properly increase boiler pressure as load is added and to operate within the environmental permit requirements.

When comparing the three systems, the approximate customer count (# of meters) for the three systems are: HECO: 292,779; HELCO: 76,144; and MECO: 59,998. This indicates that the HECO system has about 3.8 times the number of customers as HELCO. Table 5 shows a comparison of the number of substations between the three systems. Again the HECO crews needed to visit, assess and energize 3.3 times as many substations as the HELCO system and 4.5 times as many as the MECO system. This said, the HECO operations staff indicated that in most cases throughout the restoration on October 15th, the PTMs and C&M crews were on site and waiting to close in circuits before generation became available. It was only later in the evening when the majority of the generation plants were available for full capacity output and the system was stabilized that the field crews were able to close in load as quickly as possible.

HELCO's system is also reported to have a significant amount of distribution automation in place due to the larger geographic area of the HELCO grid and the greater reliance on load shedding in lieu of spinning reserve. This allows loads to be closed in remotely from the dispatch center rather than having crews drive to the locations and manually close breakers. This allows much greater flexibility in the closing sequence. HECO has reported that only about ten percent of the Oahu distribution system can be controlled remotely.

A number of outages on the U.S. mainland were assessed to see if they had any comparable relevance. In all cases, the generation mix, cause of the outages, interconnections between utilities, and in some cases extensive transmission system damage from storms, do not provide a reasonable comparison to the HECO system outage or restoration.

Table 5: HECO, HELCO and MECO Station Summary

T&D System Summary HECO, HELCO and MECO *Approximate values only	HECO	HELCO	MECO (Maui)
Transmission Substations			
138kV	17		
69kV		54	15
23kV			7
Distribution Substations	134	20	33
Total subs	**151**	**74**	**55**
Transmission Circuits			
138kV	32		
69kV		28	17
46kV	5		
Sub-transmission Circuits			
46kV	62		
34kV		6	
23kV			15
Distribution Circuits	455	133	92
Total circuits	**554**	**167**	**124**

4 Conclusions

After evaluating general system information provided by HECO, the data logs and other automatically generated information and information discussed throughout this report, along with the interviews of the operators on duty during the event and restoration, we conclude:

1. The main underlying cause of the island-wide outage was the earthquake which resulted in the false operation of OEM-installed mercury switches in the K5 and K6 Electro-Hydraulic systems that locked out the operation of the hydraulic pumps as a result of the earthquake. The control schemes for the Kahe 5 and 6 turbine steam valve actuation included lockout provisions which inhibited the pumps from re-starting, even after the low fluid level indications cleared after the earthquake. Previous generation loss due to operator trips of K3 and H8 were well within the HECO spinning and quick load pickup reserve. The E.H. lockouts resulted in the eventual loss of K5 and K6, and the spinning reserve and quick load pickup capability of the remaining units was exceeded despite the Kicker Block load shed. Loss of K5 and K6 was the primary cause of the system frequency decay to below 58 Hz. At that point, the automatic underfrequency load shed Blocks 1 and 2 operated, immediately followed by the operation of the remaining automatic underfrequency load shed Blocks 3, 4, and 5 and the near simultaneous underfrequency protective relays tripped H-Power, Kalaeloa, and AES generating units, ultimately resulting in a severe frequency drop and leading to further automatic and manual load shedding, and, eventual the island-wide blackout. These 86 LFT lockouts operating in the midst of numerous other alarms, and the resulting train of events, were likely initiated by false indications of low-low fluid levels in the E.H. reservoirs, which we believe were triggered by the earthquake acting on the mercury switches in the original equipment manufacturer's design of the plant. The annunciator panel text did not

clearly indicate the importance of the alarm, and the location of the actual lockout switch did not bring its operation readily to the attention of the operator. Had the Kahe 5-6 operators recognized the significance of the "Low Fluid Level Lockout" alarm and that the E.H. Lockout had tripped, it is very doubtful that, in the three to six minutes available before Kahe 5 and Kahe 6 lost power, they could have performed a proper inspection and determined that the "Low Fluid Level Lockout" trip was due to a false indication by a mercury switch caused by the seismic shaking.

2. The earthquake also caused numerous alarms including feedwater Heater High Level alarms on K3, K5 and K6. We believe these alarms were caused by false indications, triggered by the earthquake acting on the mercury switches provided by the original equipment makers. The numerous alarms, combined with the recent earthquake, resulted in an overwhelming effort to verify the condition of the equipment that had alarmed at K5-6. These false alarms were intermixed with numerous other alarms associated with the changing conditions in the steam plant during the quick load pickup.

3. Kalaeloa Combustion Turbine 2 tripped on underfrequency but remained on line, supplying local auxiliary or "house" load for some time, until it had to be shut down for operational reasons. The two Kalaeloa combustion turbines are 'base loaded' (that is, operated more-or-less continuously). They are therefore likely to be running at the time of any serious transmission system upset. They will tend to separate from HECO on underfrequency and "runback" to serve only the local auxiliary or house load. In the case where these units do continue to operate following a system disturbance and "island" to local load, they might be used to restart the grid, if the 138 kV substation equipment is reconfigured to allow them to close on the "dead" bus bar. The ability to make these changes, however, will be impacted by other factors such as safety considerations, permitting limitations, control and other

technical limitations of the equipment, and any contractual agreements between HECO and Kalaeloa that define requirements and obligations of both parties in such a restart situation.

4. The automatic load shed schemes appeared to have operated as planned though a number of the load shed relays failed to provide a target or had overwritten their event reports. The initial progression of frequency decay following the loss of power from K6 resulted in a relatively slow decay of system frequency and thus, despite the time delays built into the IPP's frequency trip points, the IPP generators tripped before the majority of the automatic load shed blocks activated. After the IPPs tripped on underfrequency ,the SLD initiated manual load shed in an expeditious manner but was unable to shed load fast enough to prevent system collapse as a result of the severe load to generation imbalance and the resulting rapid frequency degradation.

5. Turbine blade failure can be initiated by low frequency operation, and there is a demonstrated risk of low frequency running of steam turbines. We conclude that it would be prudent to consider the possible protection of the units from full load operation at low frequencies and we have made recommendations for possible actions on this topic.

6. The power plants, Dispatch Center and transmission system were properly configured, dispatched and staffed for normal operations the morning of Sunday October 15, 2006 at 0700 hours.

7. The actions of the HECO staff were certainly reasonable, in the best interests of the public, and amounted to a good level of performance under the circumstances. In POWER's opinion, the HECO personnel reacted to the circumstances in a reasonable, responsible and professional manner. They applied training and experience in reacting properly to the

changing system conditions based on the existing system configuration and established HECO operating practices to attempt to prevent the island-wide outage and to restore power as quickly as practical. We have considered data logs of the dispatch center, power plant units, and transmission system following the earthquake on the morning of October 15. We also reviewed statements of power plant operators and conducted direct interviews of dispatchers, PTM and C&M supervisors and operating engineers and management staff. With the advantage of calm hindsight, we can see that in a few cases there are details in which slightly different courses of action could have been taken. But we are not aware of any case where actions could be described as imprudent or likely to cause injury, or damage. We are mindful of the stress and potential confusion which can occur in the serious upset of a generating and transmission system. There can be no doubt that the operating staff, especially in the generating plant, but also in the Ward Avenue Dispatch Center, during and immediately after the earthquake at 0708 hours on October 15th, experienced serious anxiety and pressure. The situation was complicated and confused by the plethora of alarm indications, the slide of the system into blackout, and the subsequent stresses of the need to quickly restart. The HECO personnel acted professionally throughout the day applying their training and experience to their assigned tasks during a distinctly extraordinary event. The system restoration plan developed by the operations staff was reasonable based on the units which came online first and based on HECO management's historical knowledge of critical restoration issues. The plan appears to have been well executed by the PTMs, C&M crews, and Substation crews. Problems with resetting some automatic load shed breakers and high system voltages occurred but did not significantly impact the restoration duration. The pace of the restoration was balanced against the risk of tripping the generators restored to service, which would have required the system to be re-sectionalized and then re-started. HECO internal communication systems operated adequately and did not hamper restoration.

8. The power plant staff exercised reasonable judgment in the planning and execution of the black start procedures and responses to equipment failures encountered during a stressful time. The black start process was slowed due to equipment failure, troubleshooting and trips of the black start generators. The decision to proceed with black start at Kahe and Waiau minimized the time required to restore black start power to the system generators. There are indications that a couple of the Kahe plant staff on duty could have been more familiar with the black start procedures and the proper methods to connect the black start diesels to the plant auxiliaries. Part of this was due to inexperience of the operators that were involved in disconnecting the diesels from the grid and properly configuring the selected steam unit auxiliaries. However, these initial events did not significantly impact the start time as this was occurring in parallel with other activities. Also at Kahe, the trip of the black start when K3 had fires in did result in a significant delay, as the process had to be restarted with the K2 steam unit. The changing sequence due to equipment problems revealed a need to avoid miscommunication when such contingencies occur to avoid overload trip of the black start diesels when attempting to start up two units simultaneously. That said, it must be recognized that black start of the Kahe and Waiau power plants is an activity that has rarely been required, the last time being 15 years ago. Familiarity with the procedures for a significantly complex process can only come through training, rather than developing proficiency by actual application, and the training is limited by how much can be simulated with the other plants operating. With this experience, we feel that HECO could improve, through the incorporation of some contingency planning and scenarios based upon recent events, training on black start procedures.

9. The operator trips of K3 and H8 were reasonable and in the public interest considering the alarms, observations and previous experience, and considering that they each only had one turbine on line to consider as the source of the vibrations. The operators also expected, and

rightly so, that generation loss due to operator trips of K3 and H8 were well within the HECO spinning and quick load pickup reserve at the time they tripped their units. They acted in good faith to minimize damage to the turbines that could result in unit outages of several months.

10. Our opinion is that operators at both plants exercised reasonable judgment in their decisions, to attempt to "island" K1 and K2, and keep Waiau connected to the grid, given the system circumstances and HECO's operations procedures.

11. We have briefly reviewed the reports of the experiences of the electrical systems on Maui and the island of Hawaii on October 15, 2006, to consider possible comparisons with Oahu, particularly in regard to the duration of interruptions of supplies to consumers. We note that the generation technologies employed, the much smaller electrical systems, and the smaller sizes of individual generating units on Maui and the island of Hawaii, are quite different from those on Oahu. For this reason, the response to an exceptional upset such as that experienced on October 15, and the times for re-starting large-scale generation, can also be expected to be quite different. Our present conclusion, in advance of any detailed reviews of the Maui and HELCO systems, or of their responses to the October 15 earthquake, is that it is difficult to make a direct comparison between the HECO, MECO and HELCO experiences, and it could be misleading to do so. At this time we have not identified any experience or finding from events on Maui or the island of Hawaii which could be helpful to the HECO system.

5 Recommendations

In this section of this report we provide recommendations, which, if implemented, could reduce the likelihood of a repeat of the system blackout of October 15, 2006 due to similar circumstances, speed up the restoration of electricity to consumers in the event of a similar blackout, and reduce the risk of equipment damage in the event of serious system disturbance.

We recommend the following:

1. Review the control logic schemes for the motors driving the E.H. pumps which supply fluid to the actuators for the main steam valves for K5 & K6 and that operate the "86 LFT" "lockouts" on "low-low" fluid level indications. Evaluate replacement of the 86 LFT lockout with a non-latching relay while maintaining plant safety and proper operation. The controls should retain the present automatic tripping of the motors on low-low fluid levels and prevent re-starting while those low-low levels continue to be detected. The low-low fluid level alarm should also be maintained as long as the low fluid level condition is detected. We would like to note that HECO is presently acting on this recommendation.

2. Investigate replacing the mercury-type level switches used to initiate level alarms and trips for the hydraulic fluid reservoirs for the steam valve actuators, and for the horizontal feed water heaters for the Kahe units, with a type or types less likely to give false indications under earthquake conditions.

3. Assess the possible employment of the Kalaeloa combined cycle block, to allow the use of its combustion turbines to re-power "black" transmission circuits. Proceed to arrange the

capability to use the Kalaeloa combustion turbines in this manner, if they remain on line in a black-out incident, if such an evaluation identifies no safety, permit compliance, technical, or serious cost obstacles.

4. It is appreciated that HECO has a well-developed low frequency load-shedding scheme aimed at assisting overall system frequency and voltage stability. However, it is recommended that HECO arrange a study, in the light of the experience of October 15, 2006, and subsequently update to the extent appropriate its low frequency tripping scheme based on the results of the study. The study should include the effects of the IPPs' generators and their under-frequency tripping arrangement (and those of any HECO generating unit low frequency trips resulting from the analysis of recommendation 5). This update study should be directed at developing the scheme towards its objective of assisting the overall system operation, but should also extend to devise practical ways to help avoid highly-loaded operation of each of the steam turbine units below those frequencies at which each can safely operate at full load. To this end, consideration should be given to possible automatic "islanding" at very low frequencies of parts of the transmission system which the respective turbines will be able to support. Ultimately, individual tripping of steam and combustion turbines, at the lowest frequencies which they can each safely withstand at full load, should be provided. To aid in post event analysis, automatic load shed relays should be adjusted to provide proper targets for electro-mechanical relays and to prioritize data capture on microprocessor based relays to prevent overwriting of the trip records.

5. Assess the minimum frequencies at which each of HECO's steam turbine generating units can safely operate at full load (as determined by last or penultimate moving blade row vibration considerations), the assessment to include the determination of permissible durations of full load operation at various frequencies below the 60 Hz nominal. It is

important to acknowledge that given the age of the units and changes in the relevant manufacturing businesses, it may be difficult to access the original design data. It may be possible to recall data from HECO files from design or study work earlier in the lives of the units. Other methods of assessment can also be used to determine the minimum safe frequencies, and durations of operation at reduced frequencies. Provide appropriate protection for the steam turbines based on the above assessment of safe ranges of operation.

6. Visually inspect the last row of Low Pressure (LP) turbine blades on W5, 7, & 8, and K1 & 2 for cracking and/or lacing wire damage by viewing from the exhaust spaces, or when the units are out of service for other routine purposes, such as short repair or maintenance stoppages, or when the unit is not needed to meet system demand. We understand that K1's LP turbine blades were inspected during a scheduled overhaul after the earthquake. Inspection of the K1 LP section did not reveal any visible signs of damage to K1.

7. Assess the system restoration process following an island-wide blackout to determine the best order for generator startup that would allow load to be added in a safe and expeditious manner while carefully retaining frequency and voltage stability. This study should take into account 1) the sequencing of the restoration for facilities critical to stabilizing the HECO system, 2) address practical restoration of critical customer and support services on Oahu, 3) the effect of the HECO 138 kV transmission system capacitance under no-load or light-load on system voltages during restoration, 4) flexibility in the restoration process to account for differing contingencies, and 5) the use of the planned CIP CT and possible use of the Kalaeloa CTs.

8. Evaluate black start procedures and training to account for equipment failure contingencies and communications across simultaneous units black starting. Consider revision of the

procedures, development of work flows, check lists, contingency charts and other such methods to reduce possibilities for operator error and coordination of activities across the plants, considering that these are infrequent activities. The evaluation should also consider the possible use of the Kalaeloa CTs and the planned CIP CT for restart of the grid.

9. Assess the feasibility of providing additions to physical equipment and/or software for capture and storage of a reasonable dataset (e.g., a one hour snapshot period) for all DCS information, for each generating unit equipped with a DCS. The snapshot period can be manually selected up to 48 hours after an event, plus be automatically triggered by each opening of the principal unit generator or high voltage circuit breaker. Automatically triggered snapshots can be arranged to be automatically discarded a set number of days after if it is desired to limit the amount of data to be stored.

HECO's External
Communications Report

Investigation of the 2006 Oahu Island-wide Earthquake Outage

Review of External Communications on the Island of Oahu
PUC Docket 2006-0431

Prepared by Hawaiian Electric Company, Inc.
December 2006

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EXECUTIVE SUMMARY

On October 15, 2006, the effects of a 6.7 magnitude earthquake west of the Big Island of Hawaii precipitated an island-wide power outage on Oahu. As this was the strongest earthquake in Hawaii in almost 23 years and the first island-wide outage on Oahu in over 15 years, this was a rare and significant event.

Hawaiian Electric Company, Inc.'s ("HECO" or the "Company") operations personnel responding to the outage were able to communicate internally using multiple communications systems, including the Company's microwave radio system. External communications to the media and other audiences were, however, significantly hampered by technical challenges including congested phone networks, poor cellular phone reception, and loss of cellular and most land line phone service to HECO's Ward Avenue facility during the afternoon. Despite these challenges, Company personnel made concerted and ongoing efforts to keep the media, the public and key emergency responders and other government officials informed of the island-wide outage and restoration effort.

As a result of the outage and its investigation HECO has identified and is addressing several key areas for improvement.

1) Cellular Phone Service

   Loss of cellular phone service for part of the day and poor reception hampered efforts to communicate with media and key external contacts (emergency responders, government officials and large customers).

   Action Items:

   - As part of the completion of HECO's new Ward Avenue Dispatch Center, the Company had initiated a project in 2006 to install an amplifier to improve the signal strength of cellular communications within the facility. This was in progress on October 15 and has since been completed.

   - The Company is considering whether its key emergency response personnel should have access to cell phones from a backup carrier in the event one carrier loses service. However, as this recommendation will not address the inability to contact other parties who may have similar problems with their cell phones, it is recommended that a review be conducted by a coordinating emergency response agency of the battery capabilities of all cell phone carriers in Hawaii, leading to possible guidelines or requirements for minimum capabilities to maintain service in a major, prolonged power outage.

2) Land Line Phone Service

The external land line service provider for HECO's Ward Avenue facility lost power after the provider's facilities exhausted their battery capacity. Despite cooperative efforts of the service provider to address the problem, incoming phone service to Ward Avenue was unavailable for almost the entire period from 1:41 p.m. to 7:20 p.m. Some outgoing phone service was quickly restored when Company technicians rerouted the service through the alternative phone system used by its Waiau and Kahe power plants. However, limited outgoing lines still made external calling via the Ward Avenue land lines difficult during most of the afternoon.

Action Item:
- The Company is presently redesigning its land line connectivity to provide back up carrier circuits for the Ward Avenue facility to improve incoming and outgoing phone service during an island-wide outage.

3) Hotline Service

The Company's liaisons with Oahu Civil Defense (OCD) and State Civil Defense (SCD) managed to receive regular updates through various communications channels and contacts in spite of the ongoing problems with phone services.

Action Item:
- A dedicated hotline between HECO and OCD already exists. Discussions with SCD have been initiated to establish a hotline from HECO to the SCD emergency facilities in Berkheimer Tunnel.

4) Emergency Broadcast Communications

The primary means by which the public obtains information during an emergency such as an island-wide outage is the designated emergency broadcast radio station. HECO communications staff recognized this from the start of the emergency and made continuous attempts to contact the station early and then regularly throughout the day. Because HECO communications personnel were competing with the high volume of public phone calls into the main emergency broadcast radio station, they were unable to make initial contact for several hours on the morning of October 15. Later communications were hindered by ongoing phone service problems.

Despite the concerted efforts made, feedback from the general public makes it clear they expected to hear from HECO sooner and on a more regular basis throughout the outage.

Action Items:

- When appropriate, a HECO spokesperson will be dispatched to the emergency broadcast radio station to ensure more frequent utility communications with the listening audience.

- The Company will investigate options for backup communication capabilities into the EBS station (e.g., possible dedicated phone line).

- The Company's list of unpublished radio station phone numbers has been expanded and included in multiple reference locations for ready access. The list will continue to be updated on a regular basis.

5) Outage and Restoration Communication Messages

Using existing emergency preparedness materials, HECO communications staff responsibly provided early and ongoing information about food safety during an outage, unplugging sensitive electronic equipment to avoid potential damage from a power surge when power returns, safety reminders if using a portable generator, and requests to help reduce the initial load on the system upon power restoration by turning off residential water heaters at the circuit breaker. HECO spokespersons provided regular updates about which general neighborhoods had been energized. However, as is understandable, customers also wanted to know "when will MY power be restored?"

Action Items:

- Although there are too many variables to provide predictions of restoration times for specific neighborhoods[1], existing communications templates will be modified to more clearly explain the process of restoration after an island-wide outage. Such statements should incorporate a clearer explanation of the general sequence of restoration and more emphasis on the causes of pocket outages. These templates must account for the fact that the restoration path may vary with the specific conditions on the electric system for each major outage (for example, transmission line damage might require a different restoration sequence). Messages will also make clear the importance of protecting the electric grid and generators from long-term damage.

- These explanations should be provided as early as possible to all parties communicating with the public, including Customer Service representatives, liaisons with government agencies and media.

[1] See discussion in Section II, "Communications Messages," for more detailed explanation of the challenges of providing specific restoration times in advance during restoration in an island-wide outage situation.

I. INTRODUCTION AND OVERVIEW

On October 15, 2006, the effects of a 6.7 magnitude earthquake west of the Big Island of Hawaii precipitated an island-wide power outage on Oahu. As this was the strongest earthquake in Hawaii in almost 23 years and the first island-wide outage on Oahu in over 15 years, this was a rare and significant event.

Hawaiian Electric Company, Inc.'s ("HECO" or the "Company") operations personnel responding to the outage were able to communicate internally using multiple communications systems, including the Company's microwave radio system. External communications to the media and other audiences were, however, significantly hampered by technical challenges including congested phone networks, poor cellular phone reception, and loss of cellular and most land line phone service to HECO's Ward Avenue facility during the afternoon. Despite these challenges, Company personnel made concerted and ongoing efforts to keep the media, the public and key emergency responders and other government officials informed of the island-wide outage and restoration effort.

This review of external communications during the October 15 earthquake outage focuses primarily on communications (1) with the public via the media; (2) with customers who seek information through the Company's customer service communication channels, (3) with specific commercial customers and (4) with key emergency responders and other government contacts.

A. <u>Staffing</u>

Formal external communications with these audiences during the October 15 earthquake outage were primarily managed and executed by HECO's Public Affairs, Marketing Services, and Customer Service personnel, in addition to contacts made by members of the Company's emergency response Incident Command team.

All officers for these departments, as well as key managers, supervisors, and numerous staff members, arrived at the Company's Ward Avenue Dispatch Center (emergency headquarters) between 7:30 a.m. and 8:30 a.m. Additional staff arrived throughout the morning and all areas remained well staffed through the duration of the outage.

B. <u>Telecommunications challenges</u>

As will be highlighted throughout this report, external communications on October 15 were hampered by problems encountered with telecommunications equipment and networks.

- In the early hours of the outage, Company personnel experienced extreme difficulty in reaching key external contacts, including the media, due to high call volumes overwhelming available phone circuits (land line and wireless services from third party service providers).

- The initial extremely high volume of calls into the Company's published Trouble and Customer Service lines resulted in many customers receiving busy signals. (The normal remedy in such a widespread outage is to provide customers with basic system status information via the media, but as will be noted, there were problems in initially reaching the primary emergency broadcast radio station).

- Problems with communications to external parties were further compounded when:

  - The Company's phone service provider for the Ward Avenue facility lost power to parts of its system when its backup battery system ran down after more than six hours of operation. Despite cooperative efforts of the service provider to address the problem, this resulted in an inability to maintain land line phone service into the Ward Avenue facility (including the Trouble Line) for several hours during the mid-day to early evening, estimated from 1:41 p.m. through 7:20 p.m., with a roughly 10 minute period during this time when incoming phone service was temporarily restored (The service provider restored some batteries, but additional batteries subsequently drained.). As part of the Company's emergency recovery capabilities, outbound calls were rerouted through the Company's Waiau and Kahe power plants, but considerably fewer lines were available and thus the ability to call out of the Ward Avenue facility via land lines was significantly hampered for several hours during the afternoon of October 15.

  - The Company's primary wireless phone service was unavailable for several hours in the afternoon after the carrier's battery capacity for the cell site had become exhausted.

- The Company's website was not available as a communication channel to the public because the web server is located in the downtown area where power was not restored until later that evening, and the backup battery capability was exceeded. (It should be noted that although additional battery backup is now being pursued, customers without power that day would not generally have been able to access the website for information.)

II. COMMUNICATIONS WITH MEDIA

Concerted efforts were made to keep the media and public informed of the island-wide outage and restoration actions. Phone records verify that media contact occurred frequently despite major technical challenges with cellular and land line phone service. Some of these challenges were overcome by actions such as hand-delivery of press releases, regular live TV appearances (especially for the benefit of those who were able to watch the KITV streaming newscasts on CNN or to speak to mainland contacts watching CNN), and a studio visit to the primary emergency broadcast radio station for a live interview. Existing emergency response procedures that included prepared press release templates with information on concerns such as food safety, portable generator safety, and power surge concerns were used.

A. Media communication activities

1. Morning of 10/15/06:

- The earthquake struck Oahu at 7:08 a.m. Three minutes after the earthquake, HECO's Director of Corporate Communications (DCC) who is the primary media spokesperson, began making phone calls to HECO's System Operations personnel and the Corporate Communications (CC) staff person who had been assigned media duty for that weekend. At approximately 7:17 a.m., the DCC received pager reports that all automatic load shed blocks had activated by 7:14 a.m. and that more generators tripped off-line. He immediately departed from his location in Kaneohe and headed to HECO's Ward Avenue Dispatch Center. Because of clogged phone lines, attempts to reach KSSK, the primary emergency broadcast radio station, via the news center phone line during the drive to Ward Avenue were unsuccessful.

- At approximately 7:30 a.m., the DCC arrived at Ward Avenue, learned that an island-wide outage occurred at 7:27 a.m., discussed the situation with Dispatch Center personnel, and began contacting and calling in HECO CC personnel. The ability to make contact via cellular phone became intermittent and text messaging was used for some communication.

- Continued attempts to contact KSSK by calling the radio station's news center phone line were still unsuccessful due to heavy caller traffic into the station. Between 7:54 a.m. and 8:11 a.m., KITV-4, The Honolulu Advertiser and KHON-2 were notified of the island-wide outage situation. Attempts were also made to reach other media outlets. Meanwhile, the State Civil Defense Vice Director and the State Director of Transportation were notified of the situation by members of HECO's Incident Command team around 8:00 a.m. At approximately 8:15 a.m., the State Director of Transportation relayed the announcement about an island-wide outage on the air on KSSK.

- By about 8:30 a.m., the Vice President of Corporate Relations (VPCR) and most CC staff had reported to HECO's offices at Ward Avenue. A staff videographer reported to the Kahe Generating Station. CC staff continued to call the KSSK news center number without success.

- At approximately 10:00 a.m., a staff member was sent to the KSSK studio to establish contact. In parallel, access to the HECO computer network, which contained emergency communications reference materials including unpublished radio station phone numbers, was attained shortly after 10:00 a.m. Concurrently, the KSSK news director was reached via his mobile phone at 10:22 a.m. and the HECO staff member was recalled. Arrangements were made with the KSSK news director to provide regular phone updates to KSSK.

- Follow up contacts were made with KITV and The Honolulu Advertiser, as well as contacts with the Honolulu Star-Bulletin, KHNL and KGMB.

- Media communications continued to be hampered by additional technical difficulties. Cellular reception was poor within the Dispatch Center and seemed to worsen; clogged circuits prevented many calls from going out. CC staff began drafting an initial press release, informing the public to expect to be out of power for most of the day and into the evening, and providing food preservation and other safety tips. Although this first formal press release was not issued until 11:30 a.m., HECO had already made initial contact with most of the media earlier in the morning.

- When the press release was issued at 11:30 a.m., it was also read over the phone to several media stations. The Trouble Line (used to communicate HECO's phone center recorded message to callers) was updated with this information as well. Discussions with KSSK's Perry and Price occurred at 11:44 a.m. also sharing the information in the press release and the latest available updates.

2. Afternoon of 10/15/06:

Contact with the media continued, either initiated by HECO Corporate Communications personnel or in response to incoming calls. Although hampered by technology problems, contact with TV and print media and KSSK radio continued throughout the afternoon. Cellular service to the Company media line and other CC cell phones was not available from approximately 12:30 p.m. to 5:30 p.m. HECO land line incoming phone service was out for most of the period from 1:41 p.m. to 7:20 p.m. because the third party land line service provider's batteries were exhausted. Some outgoing land line service was restored. With limited success, CC staff tried to maintain communications with the media using personal cellular phones borrowed from other HECO employees who had service with other carriers.

- KITV had generator power and was streaming video on its website and through a connection that was broadcasting through Direct TV's satellite feed, which was being picked up nationally by CNN. Arrangements were made with KITV to call or meet every 60 to 90 minutes to provide updates.

- Regular updates throughout the afternoon, via phone and in person, were also provided to several reporters for The Honolulu Advertiser, which was posting online updates on its website.

- CC staff prepared the second press release, which was issued at 2:10 p.m. Because of transmission difficulties, this release was hand delivered to the media stations.

- DCC conducted afternoon on-camera interviews with KITV and KGMB.

- DCC and CC staff continued follow up calls with KHNL, KHON, KGMB, and the Honolulu Star-Bulletin.

- Update calls to KSSK were made at 12:18, 1:00, 1:33, and 3:30 p.m. (Other attempts to call in were unsuccessful due to failure of the cellular and land line phone services and network congestion.). The DCC traveled to the KSSK studio at around 6 p.m. for a live interview.

3. Early evening of 10/15/06 through early morning 10/16/06:

Media updates continued through the early evening of 10/15 and the early morning hours of 10/16.

- Additional press releases were issued at 6:30 p.m., 9:30 p.m., and 2:15 a.m. Copies of the 9:30 p.m. press release were also hand-delivered to the media, along with videotape footage of restoration efforts for the four major TV stations. Calls with updated information were also made to the TV stations to ensure information was received before the 10 p.m. newscasts.

- In addition to the formal press releases, update calls were also made throughout the evening to all four TV stations, KSSK, The Honolulu Advertiser and the Honolulu Star-Bulletin. A late-night update was also provided to Visionary Related Entertainment (radio stations KUMU, KQMQ, KDDB and KPOI).

- The Honolulu Advertiser online updates were monitored and corrected or updated as needed.

- After issuance of the 2:15 a.m. final press release announcing near total restoration of customers, update calls were made to KSSK and KITV.

- Subsequent update calls were made to KSSK at 3:32 a.m., 4:15 a.m., 5:17 a.m., 6:08 a.m. and 6:20 a.m.

- DCC provided a live call-in update at 5:01 a.m. for the KHON-2 morning news, and then arrived for an in-studio morning interview at 5:30 a.m. DCC also called in to other morning shows.

- Call-in updates to a reporter representing Cox radio and KHNL news were made at 5:11 a.m. and 6:17 a.m., KITV at 6:27 a.m. and 6:34 a.m., KRTR at 7:04 a.m., and KHNL at 7:33 a.m.

- DCC participated in an 18-minute on air interview with KHVH at 7:05 a.m.

B. Communications messages

Communications messages about the restoration effort were given considerable attention throughout the day. HECO spokespersons repeatedly communicated that restoration would take "many hours" or "into the evening." It was explained that a slow, methodical restoration process of returning power to small groups of customers at a time was necessary to maintain the stability of the electric system and to avoid the risk of destabilizing the electric system and potentially tripping generators offline again. Such consequences would result in considerable further delay in power restoration and could result in damage to utility equipment. HECO spokespersons provided regular updates about which general neighborhoods had been energized.

In addition, press releases and interviews on October 15 provided repeated reminders about food safety, unplugging sensitive electronic equipment to avoid potential damage from a power surge when power returns, safety reminders if using a portable generator, and requests to help reduce the initial load on the system upon power restoration by turning off residential water heaters by switching off the water heater circuit breaker. A detailed list of these tips was also provided to The Honolulu Advertiser and published on their website in the early afternoon of October 15.

However, as is understandable, customers also wanted to know when power to their home or business was going to be restored. Although a general planned sequence was developed for restoring service to HECO's customers, it should be noted that restoration from a total blackout is a dynamic process. The stability of the electric system, especially during the early restoration stages, is very fragile. Attempts may be made to energize a particular area, but the resulting instability on the system or other problems such as malfunctioning breakers may delay or temporarily redirect restoration efforts elsewhere. Many of these decisions are made in real time, making it difficult to make projections about the times at which specific neighborhoods are expected to be energized. In addition, on October 15 there was concern that problems might be encountered due to possible earthquake damage to relays or other equipment on the transmission or distribution systems, again delaying restoration to a particular area and redirecting restoration efforts to another area. These uncertainties were (and will always be) a real concern because raising customer expectations with a real possibility that they will not be met, which would cause further customer frustration.

Nevertheless, although it is very difficult to provide advance predictions of restoration times for specific areas, communications messages will be reviewed and revised to more clearly explain the process of restoration after an island-wide outage. Such statements should incorporate a clearer explanation of why the first areas to be energized will likely be located around the major power plants where initial power generation has been restored, and why restoration must follow the path of the transmission grid, moving in general from the plants on the west side of the island to service areas on the east side, and -- where possible, in that west to east migration -- prioritizing individual circuits serving critical customers. Such future templates must account for the fact that the restoration path may vary with the specific conditions on the electric system for each major outage (for example, transmission line damage might require a different restoration sequence).

Communications templates will also be modified to more clearly explain how the generator and electric grid protection systems work and how such protections might lead to an island-wide outage.

III. COMMUNICATIONS WITH CUSTOMERS VIA COMPANY PHONE CENTER

At 7:08 a.m. on October 15, as the earthquake hit Oahu, the Company's Customer Service Call Center was operating under a normal weekend arrangement, with public outage calls to the published Trouble Line routed to an automated trouble ticket system. This allows customers to report information about an outage at their location by entering their electric account number or a phone number previously registered with the Company for that account. Anyone without a registered phone number and/or desiring to speak to a customer service representative in person would be routed to the external answering service used during weekends and after business hours.

After the island-wide outage occurred, initial high traffic on the island's phone circuits made it very difficult for the public to successfully obtain connection to another party, including the Company or its outside answering service.

When the Customer Service Call Center supervisor reported to Ward Ave at about

8:00 a.m., calls that were able to connect into the Company's published Trouble and Customer Service lines were rerouted to receive the Company's major system recorded emergency message:

> Thank you for calling Hawaiian Electric's Automated Outage Reporting System. We are presently experiencing a major power outage. There is no need to report an outage. However, if you are calling to report a hazardous condition, such as an explosion, fire on the lines or poles, or line down, please call 911 immediately. Mahalo.

However, the volume of phone calls into the Company's Trouble line and published Customer Service number exceeded the capacity of the phone system. As a consequence, many callers were not able to reach the Company recording and instead received a fast busy signal[2].

The outage recording was updated after the 11:30 a.m. press release with excerpts from the press release, specifically adding information that:

> Customers on Oahu should expect to be out for most of the day into the evening. HECO's priority is to return power to customers as quickly as possible, but in a careful, methodical way that protects the system from damage and avoids situations where the whole process must begin again from square one.

Later, at approximately 2:15 p.m., after issuance of the second press release, the recorded message was revised to include the following information:

> To help reduce the initial demand for power as sections are restored, HECO requests customers to turn off power to electric water heaters and air conditioners by switching off the circuit breaker. Check to see that all lights are turned off. And unplug sensitive appliances, such as the television, VCR, and computer to prevent damage from a power surge that may occur when power is restored.

However, by this time, customers calling in were not able to hear this message because the external land line phone service provider serving HECO's Ward Avenue facility had already exhausted its battery backup and was unable to connect outside calls to HECO's published Trouble Line and Customer Service numbers for almost the entire period between 1:41 p.m. and 7:20 p.m.

Regular incoming phone service was restored at about 7:20 p.m. After the last distribution circuit was restored at about 1:55 a.m. on October 16, Customer Service personnel remained on duty through the early morning to receive calls and create trouble tickets for customers in pocket locations still without electric service due to other problems such as blown fuses impacting individual homes or distribution transformer problems affecting a small group of homes in a neighborhood.

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[2] The number of lines into the HECO phone system had been expanded by 30% in 2004. Such capacity is sufficient to accommodate the volume of calls for most emergencies, but not for rare occurrences such as the island-wide blackout on October 15. The normal method of communicating to customers in such a large-scale emergency is through the media; however, as discussed in this report, challenges in doing this were encountered early on.

IV. COMMUNICATIONS WITH SPECIFIC COMMERCIAL CUSTOMERS

HECO account representatives assigned to specific critical facility or larger commercial customer accounts, including the military, hospitals, large hotels, government facilities, major shopping centers, media and others, called or attempted to call their respective contacts (generally, facilities operations managers or maintenance engineers). Previously discussed problems with cellular phone service also made communications difficult. Initial calls informed customers of the island-wide blackout. Later communications conveyed that customers should expect to be out of power for much of the day, into the evening. As with all customers, commercial customers desired to know when electric service to their specific facility would be restored. Individual concerns expressed by respective customer account contacts were relayed to the appropriate HECO personnel.

In post-outage discussions, it was determined that some hospital public information officers (PIOs) felt they needed more overall information during the outage. To supplement the communication efforts of the HECO account managers, contact information for the designated central information officer for hospital PIOs has been obtained and incorporated into Corporate Communications' emergency procedures.

V. COMMUNICATIONS WITH GOVERNMENT OFFICIALS

A. State and County Civil Defense and other government agencies

At approximately 8:00 a.m. on October 15, the Company's Incident Command officials called State Civil Defense (SCD) from HECO's Ward Avenue facility and via conference call briefed the Vice Director of SCD and the State Director of Transportation about the island-wide outage. Because it did not immediately appear there was major physical statewide earthquake damage, Company officials were instructed by State Civil Defense to give priority to communication with Oahu Civil Defense (OCD) at the City & County of Honolulu Emergency Operations Center (EOC).

Communications with both Oahu and State Civil Defense continued through many channels throughout the day and into the next morning until after power was restored to substantially all customers.

At approximately 8:30 a.m., HECO's Vice President of Government and Community Affairs and a HECO senior staff engineer assigned as a Civil Defense liaison during major emergencies walked to the Oahu Civil Defense EOC to brief OCD on the electric system status. (High call volumes and service problems on land line and cellular phone systems made conducting these briefings via phone very difficult. Timely in-person briefings were made easier by the fact that the Oahu Civil Defense EOC is located near HECO's Ward Avenue facility). The HECO staff liaison remained at OCD after this briefing. Working through constraints of the phone service challenges discussed earlier, the HECO OCD staff liaison provided regular updates to City personnel located at OCD, including the OCD administrator and staff, representatives from the Mayor's office, Fire and Police departments, Board of Water Supply, Office of Environmental Services, Department of Transportation Services, and others.

A HECO staff engineer assigned as a liaison to State Civil Defense during major emergencies was briefed at the HECO Ward Avenue facility and reported to SCD at Berkheimer Tunnel between 10:30 and 11:00 a.m. Updates were provided to State and Federal personnel at SCD throughout the day and into the night. Communications with personnel at both OCD and SCD included discussion of restoration prioritization for areas and facilities such as the airport, Sand Island Wastewater Treatment plant, key military facilities, law enforcement, hospitals and Waikiki. These facilities are included among the Company's normal emergency priorities. In the case of an island-wide blackout, however, restoration must proceed very carefully, first adding customers in the vicinity of the power plants located on the west side of the island and then proceeding to pick up customers along the path of the transmission grid. Critical customers located further away from the plants cannot be restored earlier at the risk of upsetting the delicate balance between available generation and electrical load, causing damage to equipment and possibly tripping generators, which would delay restoration even further.

The liaisons to HECO OCD and SCD obtained updated information on the status of the electric system and service restoration efforts through various means during the course of the outage. An emergency phone hotline directly connects OCD and HECO's Ward Avenue Dispatch facility. Personal cell phones were also used when service from the Company's cell phone provider became unavailable in the afternoon. The SCD liaison also utilized a land line at SCD, which routed calls through a state operator, to communicate with HECO's Dispatch Center and the SCD liaison. Despite the challenges, the OCD and SCD liaisons worked through this variety of channels to keep in regular contact with each other to share and coordinate update information.

HECO's Vice President of Government and Community Affairs also provided in-person briefings to OCD after the Company's 1 p.m., 3:30 p.m. and 6 p.m. Incident Command assessment meetings. The 6 p.m. OCD briefing was video teleconferenced to SCD.

The OCD liaison left to return to HECO's Ward Avenue facility at approximately 7 p.m. when staffing at the OCD EOC was reduced; however, additional updates were provided to OCD by phone during the evening.

The SCD liaison left to return to HECO's Ward Avenue facility at approximately midnight. An additional update on system status was obtained and provided to SCD via phone shortly before 1 a.m. on October 16.

Additional communications with OCD and SCD took place through other contact points throughout the outage. HECO's Incident Commander also conferred with the Vice

Director of SCD several times in the evening, including a 2 a.m. on-site visit to HECO's Ward Avenue facility by the Vice Director of SCD.

B. Other government communications

HECO personnel also maintained communications with other government administration and agency contacts throughout the outage.

In addition to representatives from the Honolulu Police Department and Fire Department located at OCD who received information from the HECO OCD liaison and the briefings by HECO's VP of Government and Community Affairs, HPD and HFD representatives were present at HECO's Ward Avenue facility from approximately 9 a.m. until late in the evening. These representatives were briefed after each HECO Incident Command assessment meeting by HECO's VP of Government and Community Affairs.

HECO's VP of Government and Community Affairs and Senior Vice President of Public Affairs made calls to the Public Utilities Commission and the Executive Director of the Division of Consumer Advocacy and updated them during the course of the day. Regular updates were also provided to the Director of Commerce and Consumer Affairs who was with the Governor that day.

In addition, the Company conferred with officials from the State Department of Education on the status of electric service for the public schools for the following school day. By early evening, the Company communicated to DOE its commitment to restoring service in time to allow normal school operations the next day.

Corporate Communications staff also made contact with the Mayor's communications representative present at OCD, SCD communications personnel and HPD's Public Information Officer.

VI. CONCLUSIONS AND RECOMMENDATIONS

External communications on October 15, 2006 were significantly hampered by technical challenges including congested phone networks, poor cell phone reception, and loss of cellular and most land line phone service to HECO's Ward Avenue facility during the afternoon. Despite these challenges, Company personnel acted diligently and responsibly to try to keep the media, the public and key emergency responders and other government officials informed of the island-wide outage and restoration effort. Company personnel utilized alternative work-around means such as hand delivery of press releases and in-person briefings to maintain communications. Successful communications also helped to facilitate important decision making regarding electric service to public schools, enabling State DOE officials to plan accordingly.

As a result of the outage and its investigation HECO has identified and is addressing several key areas for improvement.

1) Cellular Phone Service

Loss of cellular phone communications service for part of the day and poor phone reception hindered efforts to communicate with media and key external contacts (emergency responders, government officials and large customers).

Action Items:

- As part of the completion of HECO's new Dispatch Center in 2006, the Company had initiated a project to install an amplifier to improve the signal strength of cellular communications within the facility. This was in progress on October 15, and has since been completed.

- The Company is considering whether its key emergency response personnel should have access to cell phones from a backup carrier in the event one carrier loses service. However, as this recommendation will not address the inability to contact other parties who may have similar problems with their cell phones, it is recommended that a review be conducted by a coordinating emergency response agency of the battery capabilities of all cell phone carriers in Hawaii leading to possible guidelines or requirements for minimum capabilities to maintain service in a major, prolonged power outage.

2) Land Line Phone Service

The external land line service provider for HECO's Ward Avenue facility lost power after the provider's facilities exhausted their battery capacity. Despite cooperative efforts of the service provider to address the problem, incoming phone service to Ward Avenue was unavailable for almost the entire period from 1:41 p.m. to 7:20 p.m. Some outgoing phone service was quickly restored when Company technicians rerouted the service through the alternative phone system used by its Waiau and Kahe power plants. However, limited outgoing lines still made external calling via the Ward Avenue land lines difficult during most of the afternoon.

Action Item:

- The Company is presently redesigning its land line connectivity to provide back up carrier circuits for the Ward Avenue facility to improve incoming and outgoing phone service during an island-wide outage.

3) Hotline Service

The Company's liaisons with OCD and SCD managed to receive regular updates through various communications channels and contacts in spite of the on-going communications challenges.

Action Item:

- A dedicated hotline between HECO and OCD already exists. Discussions with SCD have been initiated to establish a hotline from HECO to the SCD emergency facilities in Berkheimer Tunnel.

4) Emergency Broadcast Communications

The primary means by which the public obtains information during an emergency such as an island-wide outage is the designated emergency broadcast radio station. HECO communications staff recognized this from the start of the emergency and made continuous attempts to contact the station early and then regularly throughout the day. Because HECO communications personnel were competing with the high volume of public phone calls into the main emergency broadcast radio station, they were unable to make initial contact for several hours on the morning of October 15. Later communications were hindered by ongoing phone service problems.

Despite the concerted efforts made, feedback from the general public makes it clear they expected to hear from HECO sooner and on a more regular basis throughout the outage.

Action Items:

- When appropriate, a HECO spokesperson will be dispatched to the emergency broadcast radio station to ensure more frequent utility communications with the listening audience.

- The Company will investigate options for backup communication capabilities into the EBS station (e.g., possible dedicated phone line).

- The Company's list of unpublished radio station phone numbers has been expanded and included in multiple reference locations for ready access. The list will continue to be updated on a regular basis.

5) Outage and Restoration Communication Messages

Using existing emergency preparedness materials, HECO communications staff responsibly provided early and ongoing information about food safety during an outage, unplugging sensitive electronic equipment to avoid potential damage from a power surge when power returns, safety reminders if using a portable generator, and requests to help reduce the initial load on the system upon power restoration by turning off residential water heaters at the circuit breaker. HECO spokespersons provided regular updates about which general neighborhoods had been energized. However, as is understandable, customers also wanted to know "when will MY power be restored?"

Action Items:

- Although there are too many variables to provide predictions of restoration times for specific neighborhoods[3], existing communications templates will be modified to more clearly explain the process of restoration after an island-wide outage. Such statements should incorporate a clearer explanation of the general sequence of restoration and more emphasis on the causes of pocket outages. Such templates must account for the fact that the restoration path may vary with the specific conditions on the electric system for each major outage (for example, transmission line damage might require a different restoration sequence). Messages will also make clear the importance of protecting the electric grid and generators from long-term damage.

- These explanations should be provided as early as possible to all parties communicating with the public, including Customer Service representatives, liaisons with government agencies and media.

# # #

[3] See discussion in Section II, "Communications Messages," for more detailed explanation of the challenges of providing specific restoration times in advance during restoration in an island-wide outage situation.

VII. Appendix A - MEDIA Communications Chronology

Note: This chronology attempts to document most major media and related communications contacts made during the October 15th outage. However additional contacts may have been made using alternative phone lines, the activity for which may not be included here.

DCC = Director, Corporate Communications, CC = Corporate Communications staff, VPCR = Vice President, Corporate Relations

TIME	ACTIVITY
October 15, 2006	
7:11 – 10:30 a.m.	
7:11 a.m.	DCC initiates call to System Operations to confirm situation, calls the designated CC weekend phone duty individual at 7:13 a.m. to alert her (note: DCC's media cellular # was forwarded to the CC weekend duty individual on prior Friday).
7:17 a.m.	DCC receives several pager alerts indicating significant system problems and immediately departs for HECO – Ward Ave. Attempts to contact KSSK during the transit are unsuccessful.
7:20 a.m.	Calls to the media cell phone following the second quake. Weekend phone duty individual responds to calls beginning at 7:20 a.m.
7:30 a.m.	DCC arrives at HECO and confirms that an island-wide outage has occurred. DCC begins calls to CC personnel to report in.
7:38 a.m.	DCC calls weekend phone duty individual to advise her of his location and to alert her that the call forward feature of his phone cannot be cancelled due to cellular network problems, so she will need to continue to temporarily respond to the media calls.
7:41 a.m.	DCC contacts VPCR.
7:53 a.m.	DCC continues to reach CC staff. Other staff members call in or text message.
7:54 a.m.	DCC initiates media calls via his media contact list and connects with the following: 7:54 a.m. – KITV-4 8:09 a.m. – The Honolulu Advertiser 8:11 a.m. – KHON-2

TIME	ACTIVITY
	Continued attempts to reach the primary media contact priority, KSSK, are unsuccessful because of busy signals.
8:00 a.m. (approx)	HECO Incident Command team members inform the Vice Director, State Civil Defense and the State Director of Transportation of the situation. At approximately 8:15 a.m., State DOT director announces island-wide outage on KSSK.
By 8:30 a.m.	CC personnel report to HECO Ward Ave. One videographer heads to Kahe Power Plant. Assignments/ responsibilities are determined for each staff member.
	CC personnel continue to respond to media calls that are able to come through the cell phone lines, and also proactively try to reach other media. Most of the early reports to media confirm that there is an island-wide outage and the start of restoration efforts.
8:49 a.m.	DCC in contact with Honolulu Star-Bulletin.
9:01 a.m.	Contact made with The Honolulu Advertiser. Continuous attempts to reach KSSK are unsuccessful.
9:13 a.m.	VPCR returns call to The Honolulu Advertiser reporter.
9:15 a.m.	Corporate Communications reaches the Public Information Officer (PIO) for the Mayor's office. Attempts are made to reach the PIOs at the State Civil Defense, but the SCD land line sends callers back to the automated voice operator.
9:27 a.m.	Corporate Communications reaches the HPD PIO to provide outage information.
9:42 a.m.	Staff person assigned normal weekend media duty is in contact with KHNL.
9:48 a.m. / 10:20 a.m.	Staff person assigned normal weekend media duty is in contact with KITV.
10:00-10:30 a.m.	Begin drafting first press release, awaiting information from Incident Command Briefing to complete the release.

TIME	ACTIVITY
	Incorporated existing emergency talking points related to food, appliance and general safety.
	CC staff member is assigned to a dedicated phone with the sole task of repeatedly calling KSSK to try to get a connection for Corporate Communications.
Approx 10:00 a.m.	Staff member sent to drive to KSSK radio station to make contact.
10:20 a.m.	Staff member in contact with KITV.
10:30 a.m. – 1 p.m.	
10:22 a.m.	DCC finds KSSK News Director personal cell #, makes contact with KSSK and informs them of the situation. Both agree to contact each other regularly.
10:45 a.m., 11:21 a.m.	DCC in contact with KITV.
11:30 a.m.	VPCR in contact with The Honolulu Advertiser.
11:30 a.m.	Trouble Line phone recorded message updated with information from 11:30 press release. It included calling 9-1-1 for emergencies.
11:35 a.m.	DCC updates KSSK news director. Arrangements made to go live with Perry and Price.
11:36 a.m.	KITV calls DCC. Both agree to call each other every 60 to 90 minutes.
11:44 a.m.	DCC on air with KSSK's Perry & Price (provides information from 11:30 press release).
	Attempts are made to distribute first press release "HECO Announces Steps for Returning Power to Oahu" via computer fax and manual fax, but both transmissions fail on receiving end due to outage. Between 12:02 – 12:08 p.m., the release is read over the phone to KHON, KGMB and KHNL. From 11:36 a.m. to 1:36 p.m., DCC continues to talk to KITV (streaming video on KITV's website is being picked up by CNN), KGMB, KSSK, The Honolulu Advertiser and Honolulu Star-Bulletin about the restoration efforts, and provides food, appliance and general safety tips.

TIME	ACTIVITY
	VPCR also in regular contact from 11:30 a.m. to 12:30 p.m. with The Honolulu Advertiser, which is providing web updates.
12 noon (approx)	DCC updates KITV. KITV has backup power and is broadcasting to CNN.
12 noon (approx)	By noon, power is restored to approximately 571 customers near by Waiau Power Plant. A second release, "HECO Provides Update on Power Restoration on Oahu," is drafted.
12:30 (approx)	DCC's cell connection (media cell number) and all cell phones on the same network are out of service from approximately 12:30 to 5:30 p.m. (times estimated based on phone logs).
12:58 p.m.	DCC contacts Honolulu Star-Bulletin and KSSK.
1 p.m.	CC staff updates The Honolulu Advertiser with consumer information important during an extended outage, including minimizing/preventing food spoilage, protecting sensitive equipment from surges as power is restored, etc. This was posted on The Honolulu Advertiser website at 2:15 p.m.
1:29 p.m.	DCC updates KITV.
1:33 p.m.	DCC updates KSSK.
1:41 p.m.	Land line service for Ward Ave lost until about 7:20 p.m. (no incoming service / after rerouting, some limited external calling capability is available)
2:10 p.m.	Second press release approved and time-stamped.
Approx. 2:15 p.m.	Phone center recorded message updated.
2:00 – 6:00 p.m.	KSSK unpublished studio # is frequently busy. Unable to contact KSSK regularly. Phone service is unreliable (see previous entries on cellular and land line technical challenges).
2:30-3:00 p.m.	Since the outage continues to affect fax and e-mail transmissions, CC personnel hand-deliver the second update release to the four TV stations, KSSK, The Honolulu Advertiser and Honolulu Star-Bulletin.
3:00 p.m.	VPCR and DCC meet with KITV and The Honolulu Advertiser reporters in front of Ward Ave to provide updated information on restoration status (copy of earlier press release provided to KITV).

TIME	ACTIVITY
3:30 p.m.	Incident Command Meeting.
3:30, 3:42 p.m.	DCC contacts KSSK and KITV via personal cellular. Arranges TV interview with KITV.
4:00 p.m.	DCC goes on camera with KITV and KGMB in front of Ward Avenue headquarters.
4:07-4:18 p.m.	CC staff updates KHON, KGMB and KHNL as follow up to the 2:10 p.m. time-stamped release.
5:10 p.m.	VPCR provides update to The Honolulu Advertiser.
5:14 p.m., 5:45 p.m., 6 p.m.	VPCR provides updates to Honolulu Star Bulletin.
5:30 p.m.	DCC on-camera interview with KITV in front of Ward Avenue headquarters around 5:30 p.m. 5 p.m. coverage on KITV, KHNL and KGMB; 6 p.m. coverage on KHON.
5:38 p.m.	DCC updates KHNL.
6:00 – 6:15 p.m.	DCC gives in-person interview at KSSK studio.
6:30 – 10:30 p.m.	
	Corporate Communications continues to initiate as well as respond to ongoing media queries.
	A third release, "HECO Makes Progress on Oahu Power Restoration," is prepared. As of 6:30 p.m., over 86,000 customers have electric service, including the airport, Pearl Harbor and Hickam Air Force Base. HECO reminds customers that the process will be slow and methodical, and that crews will work through the night to restore electricity to everyone. Press release was faxed and read to the media via phone.
6:41 p.m.	DCC updates The Honolulu Advertiser.
7:13 p.m.	DCC updates KGMB.
7:20 p.m.	VPCR updates Honolulu Star-Bulletin.
7:33 p.m.	DCC updates KITV.

TIME	ACTIVITY
7:54 – 8:00 p.m.	DCC updates The Honolulu Advertiser.
8:02 p.m.	VPCR reaches SCD communications personnel (is informed that they were satisfactorily updated via video link to Oahu Civil Defense by HECO VP of Govt. and Community Affairs).
8:16 p.m.	The Honolulu Advertiser posts online update on 91,000 customers restored after phone interview with DCC.
8:50 p.m.	DCC updates KHNL.
8:54 p.m.	DCC updates The Honolulu Advertiser
9:00 p.m.	Coverage on KFVE.
9:02 p.m.	The Honolulu Advertiser posts online update on 114,000 customers restored after phone interview with DCC.
	Video footage of the restoration efforts is compiled on DVD cam tape for media use.
9:26 p.m./ 9:44 p.m.	VPCR updates The Honolulu Advertiser and Honolulu Star-Bulletin.
9:29 p.m.	DCC calls KSSK.
	A fourth update release, "HECO Continues to Make Progress on Power Restoration," is prepared and time-stamped 9:30 p.m. Corporate Communications staff hand-deliver the release with video footage of Company restoration operations to the four TV stations by 10 p.m.
9:40 p.m.	Call to KHON to update before 10 pm news.
9:44 p.m.	Call to KHNL to update before 10 pm news.
9:44 p.m.	Call to KGMB to update before 10 pm news.
9:45 p.m.	The Honolulu Advertiser posts online update on 134,000 customers restored after phone interview with DCC.
9:48 p.m.	The Honolulu Advertiser team coverage of earthquake and power outage is posted online.
10:00 p.m.	News coverage airs on KHON, KITV, KHNL and KGMB.

TIME	ACTIVITY
10:05 p.m., 10:28 p.m.	VPCR provides updates to The Honolulu Advertiser.
10:30 p.m. – 3:30 a.m. (10.16.06)	
	Update fax to KSSK, and call made to The Honolulu Advertiser night city desk reporter regarding restoration update at 11:30 p.m. (202,000 customers restored).
11:21 p.m.	Update provided to Honolulu Star-Bulletin.
11:42 p.m.	DCC updates Visionary Related Entertainment (radio stations KUMU, KQMQ, KDDB and KPOI).
12:14 a.m.	The Honolulu Advertiser posts online update (202,000 customers restored).
	CC midnight shift employee responds to calls from Visionary Related Entertainment (KQMQ, KUMU, KDDB and KPOI), KITV and The Honolulu Advertiser. Also contacted The Honolulu Advertiser to correct online information.
October 16, 2006 **(early morning only)**	
1:01 a.m.	Call made to The Honolulu Advertiser to provide latest update (234,000 customers restored) and same update given to KITV.
2 a.m.	KHON news update airs.
2:15 a.m.	The final update release, "HECO Power Restoration Update," is faxed. All customers restored as of 1:55 a.m. with pocket outages still affecting some areas. Instructions provided that those without power in pocket areas should call in to report outages. Follow up calls made to KHNL, KSSK and KITV. Stations also called in to request on camera interviews for morning shows.
2:38 a.m.	The Honolulu Advertiser posts online update "Power restored island-wide."
3:30 a.m.	KSSK news director (and national stringer) calls for final update.
4 a.m.	KITV news update airs.

TIME	ACTIVITY
4:15 a.m.	DCC checks in with KSSK.
5:01 a.m.	DCC provides update for KHON-2 morning news.
5:30 a.m.	DCC does in-studio interview with the KHON-2 morning news.
5:11, 6:16 a.m.	DCC updates reporter for Cox Radio/KHNL-8.
5:17, 6:08, 6:20 a.m.	DCC updates KSSK and starts multiple dialogs with KSSK due to 'pocket outage' customers having trouble contacting HECO via trouble and call center phones. DCC calls in a "work around" to KSSK listeners, takes outage locations from KSSK listeners.
6:27, 6:34 a.m.	DCC updates KITV.
7:04 a.m.	DCC updates KRTR.
7:05 a.m.	DCC does 18 minute on-air interview with KHVH.
7:33 a.m.	DCC updates KHNL.
8 a.m.	KHNL news update airs.
8:31 a.m.	VPCR updates Honolulu Star-Bulletin

VIII. Appendix B – Press Releases

Following are press releases distributed to media on October 15 and October 16 regarding the island-wide power outage and restoration progress.

Hawaiian Electric Company

NEWS • RELEASE

Contact: Jose Dizon
223-9932

FOR IMMEDIATE RELEASE
October 15, 2006
11:30 a.m.

HECO Announces Steps for Returning Power to Oahu

Honolulu, Hawaii: Oahu experienced an island-wide power outage this morning following the earthquake leaving approximately 291,000 customers without power. Hawaiian Electric Company's system operated as programmed. After the first units tripped out due to the earthquake, the system detected that load was greater than generating capacity and additional power generators shut down to protect the system from long-term damage.

Customers on Oahu should expect be out for most of the day into the evening, although some customers may be returned to power more quickly. HECO's priority is to return power to customers as quickly as possible, but in a careful, methodical way that protects the system from damage and avoids situations where the whole process must begin again from square one. As always, the safety of the public, HECO customers and crews has the highest priority.

At this time, HECO crews are simultaneously checking the transmission systems, substations and power generators for any damage as a result of the earthquake and preparing the generators for restart, a lengthy process. Preliminary assessments have been completed and work is proceeding to restart the system gradually, bringing electrical load on a little at a time, rather than in big chunks.

"Recovery is our priority," said Jose Dizon, HECO spokesman. "But customers should understand that doing so in a safe, methodical way will take some time and our customers should plan accordingly. We will keep the media posted as we progress."

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IMPORTANT INFORMATION:

Immediate health and safety concerns:

Persons with immediate health and safety concerns should contact 911.

Preparing for return to power:

During a power outage, a fully-stocked free-standing freezer will keep most of your foods frozen for up to seventy-two hours -- if you don't open the door! The freezer section of a refrigerator-freezer will keep most of your foods frozen ten to twenty-four hours. Don't peek inside to see if the food is still frozen...each time you open the door, cold air gets out!

Unplug your sensitive electrical appliances such as your television, VCR, and computers by shutting them off and unplugging them. Check to see that all your lights are off, and that all sensitive equipment is unplugged to prevent damage from a power surge that may occur when the power is restored.

If you use an emergency generator at home:

Connecting a portable generator can cause safety problems if not done properly. When using a portable generator, HECO asks that you carefully follow instructions in the manufacturer's manual, for your safety and the safety of HECO employees working to restore electricity to the HECO system.

As a general rule, don't plug household electrical outlets to the generator. Instead: Plug your equipment or appliance directly into the generator; make sure the wattage requirements of the appliance don't exceed the capacity of your generator or extension cord. Also, be sure to provide adequate ventilation for exhaust and cooling. And store reserve fuel in a safe place away from the generator or any other equipment that might ignite the fuel; use containers designed for fuel storage.

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Hawaiian Electric Company

NEWS • RELEASE

Contact: Jose Dizon
223-9932

FOR IMMEDIATE RELEASE
October 15, 2006
2:10 p.m.

HECO Provides Update on Power Restoration on Oahu

Honolulu, Hawaii: Hawaiian Electric Company has started some of its power generators at the Waiau Power Plant, following the island-wide power outage experienced this morning. A small group of customers, nearly 13,000, near the Waiau Power Plant now has electric service.

HECO wants to advise customers that restoring power is a slow, methodical process. Small groups of customers in the vicinity of the power plants will be brought online incrementally to maintain stability in the system. The generation output and the demand for power need to be equalized.

"We are pleased that we are beginning to restore power and we appreciate customer's patience." said Jose Dizon, HECO spokesman. "However, customers should understand that full restoration will take many hours and they should plan accordingly."

To help reduce the initial demand for power as sections are restored, HECO requests customers to turn off power to electric water heaters by switching off the water heater circuit breaker. Check to see that all the lights are turned off. And unplug sensitive appliances, such as the television, VCR, and computer to prevent damage from a power surge that may occur when the power is restored.

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Here are some guidelines for food safety -- butter, margarine, and hard cheeses are safe unless mold or rancid odors develop. Fresh fruits and vegetables are safe as long as they aren't mushy or slimy. Eggs will be safe for several days if the shells have no cracks. Fresh meat, poultry, luncheon meats or hot-dogs should be discarded if allowed to warm to room temperature for more than two hours. Milk and cream probably will sour after eight hours without refrigeration. Vinegar and oil salad dressings, jellies, jams, mustard, pickles, and olive may be safely kept un-refrigerated unless they have been contaminated by poultry or meat juices.

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Hawaiian Electric Company

NEWS • RELEASE

Contact: Jose Dizon
223-9932

FOR IMMEDIATE RELEASE
October 15, 2006
6:30 p.m.

HECO Makes Progress on Oahu Power Restoration

Honolulu, Hawaii: Hawaiian Electric Company (HECO) has made progress restoring power to Oahu, following the island-wide power outage experienced this morning. Power generating units at Waiau and Kahe Power Plants have been brought online. As of 6:30 p.m. over 86,000 customers have electric service.

Power has primarily been restored to Leeward parts of the island, including Pearl City, Aiea, Waianae, Nanakuli, Makaha, Waipahu, Mililani, Waialua, and Wahiawa. Other parts of the island that now have power include Keehi, Makalapa, Sand Island, Iwilei, and areas near Neal Blaisdell Center. The Honolulu International Airport, Pearl Harbor, and Hickam Air Force Base have also been restored.

"We have made progress as we carefully and safely restore power to Oahu and we will continue to work into the night until all customers have electricity," said Jose Dizon, HECO spokesman.

HECO asks customers, both residential and business, who are still out of power to assist in the restoration process by shutting off appliances and equipment that draw large amounts of electricity, such as air conditioners and electric water heaters. These measures will help provide stability to the electrical system as customers are gradually brought online.

Customers should also unplug sensitive appliances, such as televisions, VCRs, and computers, to prevent damage from a power surge that could occur when power is restored.

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Hawaiian Electric Company

NEWS • RELEASE

Contact: Jose Dizon
223-9932

FOR IMMEDIATE RELEASE
October 15, 2006
9:30 p.m.

HECO Continues to Make Progress on Power Restoration

Honolulu, Hawaii: Hawaiian Electric Company (HECO) continues to restore power to customers on Oahu, following the island-wide power outage experienced this morning. HECO continues to bring power generators online, including the power generators at the independent power producers. As of 9:30 p.m. over 136,000 customers have electric service.

Power has been restored to most of the following areas: Pearl City, Aiea, Waianae, Nanakuli, Makaha, Waipahu, Pearl City, Ewa Beach, Kunia Makai, Waialua, Haleiwa, Wahiawa, Helemano, Mililani, Waimano, Waimalu, Hala, Keehi, Makalapa, Sand Island, Iwilei, Kewalo, Archer, Piikoi, Kapahulu, Kaimuki, Kahala, Kawela, Olomana, Mokapu, Keolu, and Kaneohe Marine Corps Base have power.

"We will continue to work through the night until all customers have electricity," said Jose Dizon, HECO spokesman. "We thank customers for their patience and apologize for the inconvenience caused by the outage."

To maintain stability on the system as power is gradually restored HECO asks residential and business customers who are still without power to shut off appliances and equipment that draw large amounts of electricity, such as air conditioners and electric water heaters.

Customers should also unplug sensitive electronic appliances, such as televisions, VCRs, and computers, to prevent damage from a power surge that could occur when power is restored.

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Hawaiian Electric Company

NEWS • RELEASE

Contact: Sharon Higa
223-9932

FOR IMMEDIATE RELEASE
October 16, 2006
2:15 a.m.

HECO Power Restoration Update

Honolulu, Hawaii: As of 1:55 a.m. on Monday, October 16, Hawaiian Electric Company has restored nearly all of the approximately 290,000 customers on Oahu affected by the island-wide power outage following the Sunday morning earthquake. Small pockets of customers may still remain without power, and are advised to call the HECO trouble line at 548-7961 to report the outage.

This is the final update.

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